Fecal Coliform TMDL for Little Creek Watershed, Virginia

Submitted by

Virginia Department of Environmental Quality

Virginia Department of Conservation and Recreation

Prepared by

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Executive Summary

This report presents the development of Fecal Coliform Total Maximum Daily Load (TMDL) for the Little Creek. Little Creek is located in the South Fork Holston River watershed as part of the Tennessee Big-Sandy River Basin, hydrologic unit code (HUC) 06010102, in the southwest portion of Virginia.

Little Creek was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) due to violations of the State's water quality standard for fecal coliform at one Tennessee monitoring station just downstream of the Virginia/Tennessee state line. Ten samples were collected within a 30-day period in 1996, eight of ten samples had fecal coliform values over 1,000 colonies per 100 milliliters. The geometric mean calculated for these 10 samples violated the Virginia standard for fecal coliform. Tennessee Department of Environment and Conservation published results of three studies: "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, June 28 through July 27, 1993," "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, June 5 through June 29, 1995" and "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, August 5 through September 3, 1996." All three studies showed fecal coliform violations at the Little Creek sampling station located at river mile 0.10.

The Little Creek watershed is approximately 5,520 acres or 8.64 square miles. The watershed is located in two jurisdictions: Washington County and the City of Bristol. The dominant land uses in the watershed are forest, improved pasture and open urban land. The forest land use accounts for 41% of the watershed land area. Improved pasture accounts for 20% of the watershed. Open urban land accounts for 10% of the watershed. The combination of these three land uses account for 71% of the land area of the watershed. A complete characterization of the watershed is presented in Section 3.0 of this report.

Little Creek flows through both rural and urban settings. Potential sources of fecal coliform include point sources and land-based sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven. For example, fecal coliform bacteria from the land-based sources (agricultural and urban runoff) will be most critical during wet weather conditions. The failed septic system loading is considered constant over time, but it will be most critical during dry weather and stream low-flow conditions. Section 3 of this report includes a detailed assessment of fecal coliform sources and a presentation of how the loadings from these sources were estimated.

In the Little Creek watershed, two bacteria source tracking sampling stations were set up and water quality samples were collected and analyzed on a monthly basis from September 2001 through February 2002. Four categories of sources were considered: human, wildlife, livestock, and pets. The BST results for six sampling events on a monthly basis at two stations located on Little Creek are presented in Section 3. The data indicated that fecal coliform bacteria from human, wildlife, livestock, and pets were present in Little Creek. The human signature ranged from 8 to 54%; the wildlife signature ranged from 0 to 42%; the livestock signature ranged from 13 to 38%; and the pets signature ranged from 17 to 58%.

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions of Little Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Little Creek model were used to develop the TMDL allocations based on the existing fecal coliform load. The HSPF model was set up and calibrated based on the Beaver Creek flow data and watershed characteristics. This was done because there is no available stream flow data for Little Creek and the Little Creek is a tributary of Beaver Creek therefore these watersheds are hydrologically similar. The hydrologic similarity between the two watersheds was established based on the land use conditions and soil types.

Section 4 of this report describes the modeling approach used in the Little Creek TMDL development. The primary focus is on the sources representation in the HSPF model, assumptions used, the model calibration and validation, and the existing load.

The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios will be calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety, 5% of TMDL.

Based on load allocation scenario analysis, a TMDL allocation plan to meet the 30-day geometric mean water quality standard goal of 190 cfu/100 ml requires:

- 100 percent reduction of human sources of fecal coliform from failed septic systems and straight pipes,
- 100 percent reduction of the direct instream fecal coliform loading from livestock, and
- 70 percent reduction of the fecal coliform loading from wildlife.

A summary of the fecal coliform TMDL allocation plan loads for Little Creek is presented in Table E-1.

Table E-1: Little Creek TMDL Allocation Plan Loads (cfu/year)

Point Sources (WLA)	Nonpoint source (LA)	Margin of safety (MOS)	TMDL
8.29E+09	2.63E+14	1.58E+13	2.79E+14

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are:

1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved;
2) it provides a measure of quality control, given the uncertainties that exist in any model;
3) it provides a mechanism for developing public support;
4) it helps to ensure the most cost effective practices are implemented first; and
5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

The development of the Little Creek TMDL would not have been possible without public participation. The first public meeting was held in the City of Bristol on December 6, 2001 to discuss the process for TMDL development, source assessment input, and bacterial source tracking data; 17 people attended. The second public meeting was held in the City of Bristol on March 7, 2002 to discuss the draft TMDL; 22 people attended. Copies of the presentation were available for public distribution. The meetings were public noticed in the Virginia Register. A public meeting notice newsletter was prepared by DEQ and mailed to county and city residents. A public meeting notice was also e-mailed to members of two local watershed groups: Boone Watershed Partnership and Beaver Creek Watershed Alliance. A public meeting notice was published in the Bristol Herald prior to the meetings. The public comment period ended on April 15 2002.

1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (EPA, 1991).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). The DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to better develop and regulate a more effective TMDL process. The role of the DEQ is to act as a lead agency for the development of statewide TMDLs. The DEQ focuses its efforts on all aspects of pollution reduction and prevention to the state waters. DEQ ensures compliance with the Clean Water Act and the Water Quality Planning Act, as well as encourages public participation throughout the entire process. The role of DCR is to initiate nonpoint source pollution control programs on a state-wide level through the use of grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Elimination System Discharge Permits (NPDES) from industrial and mining operations. Lastly, the VDH monitors shellfish waters for fecal coliform, classifies waters for shellfish growth/harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001a).

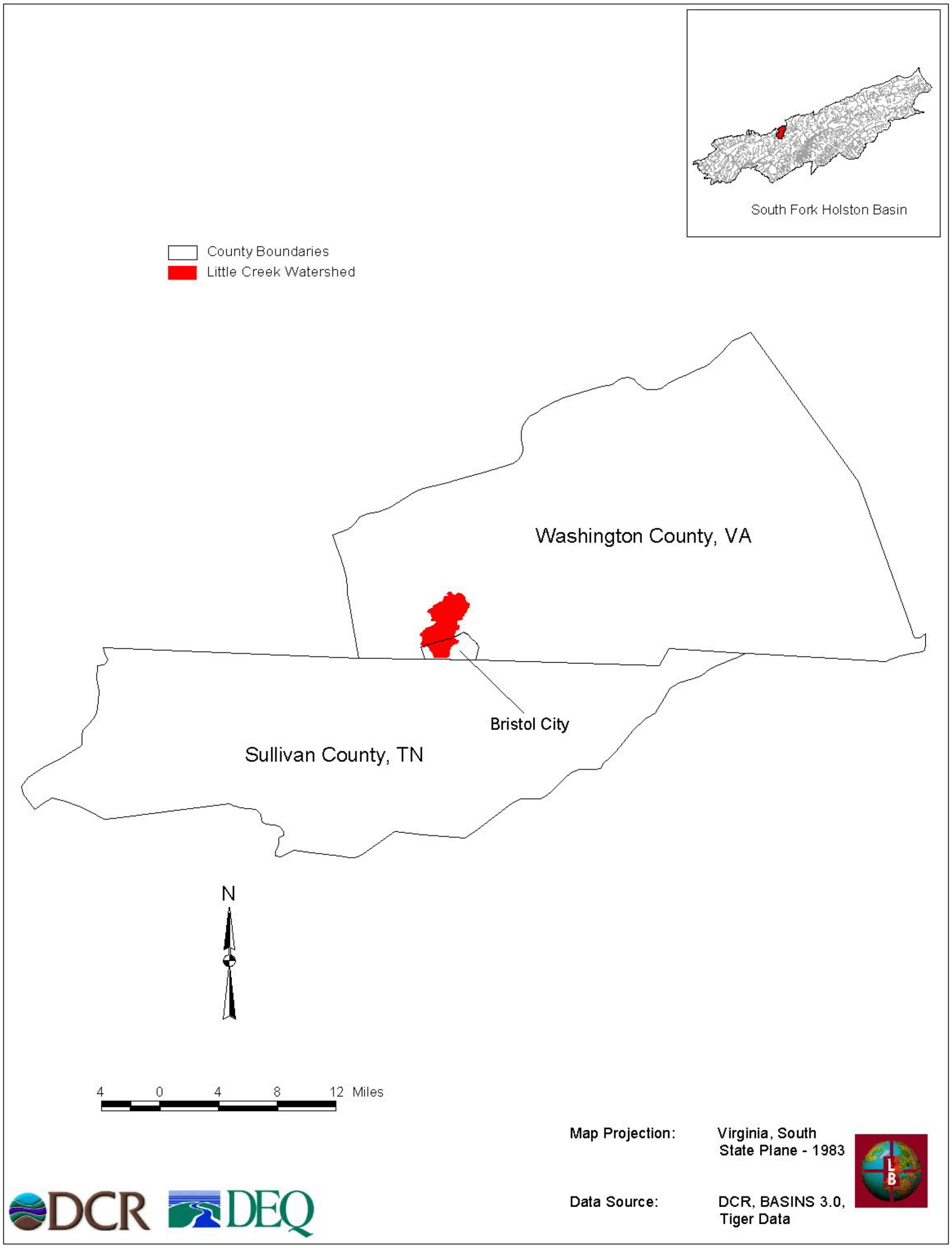
Since 1992 DEQ has developed a list of impaired waters that details the pollutant(s) in violation and the potential source(s) of the pollutant (DEQ, 2001). The Water Quality, Monitoring, Information, and Restoration Act was passed in 1997 by the Virginia General Assembly to guide DEQ in creating and implementing TMDLs for the state waters on the 303(d) list (DEQ, 2001a). The 1998 303(d) report for the state of Virginia lists Little Creek (ID# VAS-O07R-02) as impaired for fecal coliform.

As required by the Clean Water Act and the Water Quality Planning and Management Regulations, once the TMDL has been developed it should be distributed for public comment and then submitted to the EPA for approval.

1.1.2 Watershed Overview

Little Creek is located in the South Fork Holston River watershed as part of the Tennessee Big-Sandy River Basin, USGS hydrologic unit code (HUC) 06010102, in the southwest portion of Virginia (Figure 1-1). Little Creek runs through Washington County and City of Bristol, and extends into Tennessee where it eventually drains into the South Fork of the Holston River.

Figure 1-1: Location of the Little Creek Watershed

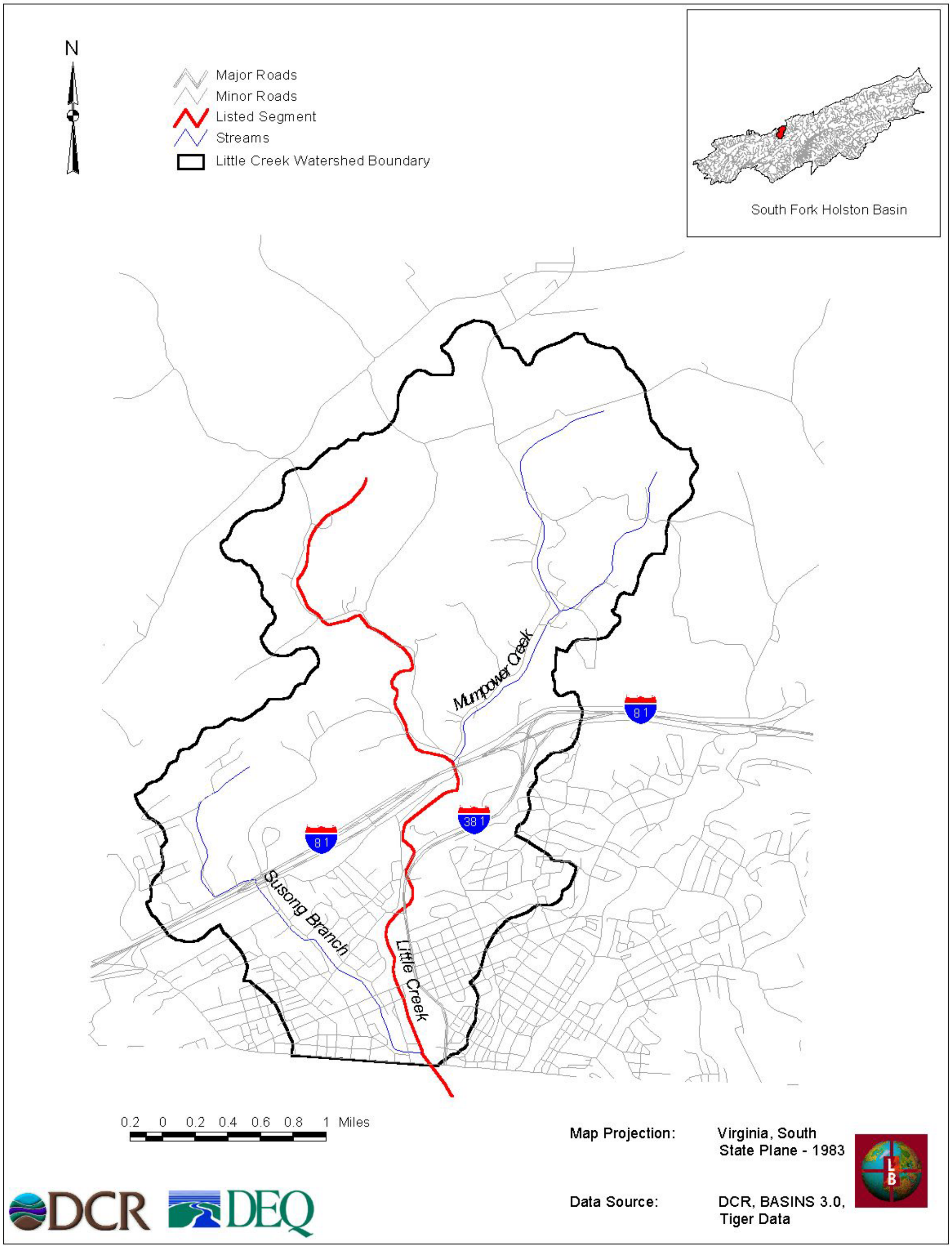


1.2 Impairment Listing

Little Creek was listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) due to violations of the State's water quality standard for fecal coliform at one Tennessee monitoring station just downstream of the Virginia/Tennessee State Line. Ten samples were collected within a 30 day period in 1996; eight of ten samples had fecal coliform values over 1,000 colonies per 100 milliliters. The geometric mean calculated for these ten samples also violated the Virginia geometric mean standard for fecal coliform. Tennessee Department of Environment and Conservation published results of three studies, "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, June 28 through July 27, 1993," "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, June 5 through June 29, 1995" and "Bacteriological Screening Survey Beaver Creek Sullivan County, Tennessee, August 5 through September 3, 1996." All three studies showed fecal coliform violations at the Little Creek sampling station located at river mile 0.10.

Little Creek is located in Washington County and the City of Bristol and is part of the Tennessee Big Sandy River Basin. The impaired segment is 5.52 miles in length. It begins at the headwaters and continues downstream to the Tennessee state line. Figure 1-2 is a map showing the listed Little Creek segment.

Figure 1-2: Little Creek Watershed Listed Segment



1.3 Applicable Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term

> *"…water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality if water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

1.3.2 Applicable Water Quality Criteria

For a non-shellfish supporting waterbody to be in compliance with Virginia fecal coliform standards for contact recreational use, DEQ specifies the following criteria (9 VAC 25-260-170):

> *"…the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 mL at any time."*

If the waterbody exceeds either criterion more than 10% of the time, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion is applied to a particular datum or data set (9 VAC 25-260-

170). If the sampling frequency is one sample or less per 30 days, the instantaneous criterion is applied; for a higher sampling frequency, the geometric criterion is applied.

For Little Creek, the TMDL is required to meet the geometric mean criterion since the computer simulation gives daily fecal coliform concentrations, analogous to daily sample collection. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

1.3.3 Water Quality Standards Review

Two regulatory actions related to the fecal coliform water quality standard are currently underway in Virginia. The first rulemaking pertains to the indicator species used to measure bacteria pollution. The second rulemaking is an evaluation of the designated uses as part of the state's triennial review of its water quality standards.

1.3.3.1 Indicator Species

EPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

1.3.3.2 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 and on page 1–6. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

In the TMDL public participation process, the residents in these watersheds often report that "people do not swim in this stream." It is obvious that many streams within the state are not used for recreational purposes.

Additionally, DEQ and DCR have developed fecal coliform TMDLs for a number of impaired waters in the state. In some of the streams, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or "typing" of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl contribute to the elevated fecal bacteria counts in these streams.

Recognizing that all waters in the Commonwealth are not used extensively for swimming, Virginia is considering re-designation of the swimming use for secondary contact in cases of: 1) natural contamination by wildlife, 2) small stream size, and 3) lack of accessibility to children. The widespread socio-economic impacts resulting from the cost of improving a stream to a "swimmable" status are also being considered.

The re-designation of the current swimming use in a stream will require the completion of a Use Attainability Analysis (UAA). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

Another option that EPA allows for the states is to adopt site-specific criteria based on natural background levels of fecal coliform. The state must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs. As in the case for UAAs, all site-specific criteria must be adopted as amendments to the state's water quality standards regulations.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Little Creek, in Washington County Virginia, was placed on the 1998 303(d) list for fecal coliform bacteria in violation of state standards for contact recreation uses. The TMDL focuses on 5.52 miles of Little Creek, starting at its headwaters and ending at the Virginia/Tennessee state line in the City of Bristol, Virginia.

One of the first steps in developing TMDLs is determining the numeric endpoints, or water quality goals/targets for each waterbody. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Little Creek TMDL are established in the Virginia water quality standards (9 VAC 25-260-20), which states that all waters in the state should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore, the current water quality target for Little Creek, as stated in 9 VAC 25-260-170 (see page 1-4), is a fecal coliform count where the geometric mean is not greater than 200 counts per 100 ml for two or more water quality samples taken in a 30-day period or greater than 1,000 counts per 100 ml of water at any time.

2.2 The Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Little Creek. If the TMDL is developed such that the water quality target is met under these conditions, then the water quality target would be met under all other conditions.

Little Creek flows through both rural and urban settings. Potential sources of fecal coliform include point sources and land-based sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, pets, and wildlife. Some of these sources are dry weather driven and others are wet weather driven. For example, fecal coliform bacteria from the land-based sources (agricultural and urban runoff) will be most critical during wet weather conditions. The failed septic system loading is considered constant over time, but it will be most critical during dry weather and stream low-flow conditions.

Because fecal coliform loadings result from sources that can contribute during wet weather and dry weather, a critical condition cannot be determined from the available water quality data. Review of the available water quality data for Little Creek indicated that the violation of the 200 cfu/100 ml standard occurred during all months of the year. Instead the fecal coliform loading from direct or point sources and nonpoint sources and the instream water quality conditions of Little Creek response were considered under various hydrological conditions. These would include typical, or average, wet and dry hydrological conditions. The model was run under these various hydrological conditions to account for wet weather and dry weather periods. The model demonstrated that the geometric mean violations were occurring predominantly under low flow periods. Therefore low flow periods are the critical condition and direct sources which dominant under such hydrologic conditions have to be reduced in order to meet the geometric mean standard.

3.0 Watershed Description and Sources Assessment

In this section, the types of available data and information collected for the development of the Little Creek TMDL will be presented. This information was used to characterize Little Creek and its watershed and to inventory and characterize the potential point and nonpoint sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Watershed physiographic data that describe the watershed physical conditions such as the topography, soils and land use;
(2) Hydrographic data that describe the stream physical conditions such as the stream channel depth, width, slope and elevations;
(3) Data and information related to the use and activities in the watershed that can be used in the identification of potential fecal coliform sources; and
(4) Environmental monitoring data that describe the stream flow and the water quality conditions in the stream.

Table 3-1 shows the various data types and the data sources used in the Little Creek TMDL.

Table 3-1: Inventory of Data and Information Used in the Development of the Little Creek TMDL

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DCR
	Land use/land cover	DCR
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS; DCR; USACE, Nashville District
	Stream morphology	
Weather data	Hourly meteorological conditions	Bristol Airport, NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR nutrient management specialist, Holston River Soil and Water Conservation District, TVA
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Washington County Health Department, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMR)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient instream monitoring data	DEQ, TVA, TDEC
	Stream flow data	USGS

Notes:
BASINS: Better assessment Science integrating Point and Nonpoint Sources
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NRCS: Natural Resources Conservation Service
TDEC: Tennessee Department of Environment and Conservation
TVA: Tennessee Valley Authority
USACE: U.S. Army Corps of Engineers
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

3.2.1 Watershed Boundaries

Little Creek is a tributary of the South Fork Holston River as part of the Tennessee-Big Sandy River Basin. The Little Creek watershed is approximately 5,520 acres or 8.64 square miles. The watershed is located in two jurisdictions: Washington County and the City of Bristol. Seventy percent of the watershed land area is located in Washington County and thirty percent of the watershed is located in the City of Bristol. Interstate Highway 81 (I-81), which runs through the watershed in a southwesterly direction, represents the dividing line between these two jurisdictions. The land area north of I-81 is in Washington County and the land area south of I-81 is in the City of Bristol.

3.2.2 Topography

The digital elevation model (DEM) and the USGS 7.5 minute quadrangle maps were used to characterize the topography in the watershed. The DEM data was obtained from BASINS (Better Assessment Science Integrating Point and Nonpoint Sources, see glossary) and compared to the Bristol and Wallace, Virginia USGS 7.5-minute quadrangle maps. The elevation in the watershed ranged from 1,680 to 2,460 feet above mean sea level.

3.2.3 Soils

The Little Creek watershed soil characterization was based on the STATSGO data obtained from BASINS. The soil series, Frederick-Carbo-Timberville association, is the dominant soil type in the watershed. Within this soil association, two hydrologic groups—B and C—may exist, which represent the infiltration capacity of the soil. Table 3-2 shows the soils map unit id, hydrologic soil group designations and a brief description of each soil.

Table 3-2: Soil Types and Characteristics in the Little Creek Watershed

Map Unit ID	Hydrologic Group	Soil Association	Characteristics
VA 003	B	Frederick-Carbo-Timberville	Moderate infiltration rates. Deep and moderately deep, moderately well and well drained soils with moderately coarse textures.
VA 003	C	Frederick-Carbo-Timberville	Slow infiltration rate. Soils with layers impeding downward movement of water, or soils with moderately fine or fine textures.

Source: NRCS, 2000.

3.2.4 Land Use

Land use characterization was based on data provided by DCR for the Little Creek watershed. DCR developed this digital land use/land cover data using satellite images, digital ortho quads (DOQQ), and extensive ground truthing. The land uses that are present in Little Creek are presented in Table 3-3, which shows the land use distribution in the watershed by area and percentage. The table shows that dominant land uses in the watershed are forest, improved pasture and open urban land. The forest land use accounts for 41% of the watershed land area. Improved pasture accounts for 20% of the watershed. Open urban land accounts for 10% of the watershed. The combination of these three land uses account for 71% of the land area of the watershed. Brief descriptions of the land uses are presented in Table 3-4.

Table 3-3: Land Use Distribution in Little Creek Watershed

Land Use Category	Land Use Type	Acres	Percent of Watershed's Land Area
Residential	High Density Residential	308.20	5.58
	Mobile Home Park	7.60	0.14
	Medium Density Residential	78.90	1.43
	Low Density Residential	73.19	1.33
	Wooded Residential	4.34	0.08
Urban	Mixed Urban or Built-up Land	4.99	0.09
	Transportation	230.02	4.17
	Industrial	105.37	1.91
	Commercial & Services	126.52	2.29
	Open Urban Land	565.15	10.24
	Barren	1.50	0.03
Agriculture	Crop Land	96.02	1.74
	Improved Pasture	1118.58	20.26
	Unimproved Pasture	219.41	3.97
	Grazed Woodland	14.57	0.26
	Harvested Forest Land	8.29	0.15
	Cattle Operations	2.70	0.05
	Overgrazed Pasture	262.69	4.76
	Orchards, Nurseries	1.43	0.03
	Farmstead	13.59	0.25
Forest	Forested	2269.87	41.12
Other	Unmanaged Grasslands/CRP*	1.22	0.02
	Water	2.60	0.05
	Wetlands	3.22	0.06
	Total	5519.97	100.00

*CRP: Conservation Reserve Program

Table 3-4: Descriptions of Land Use Types

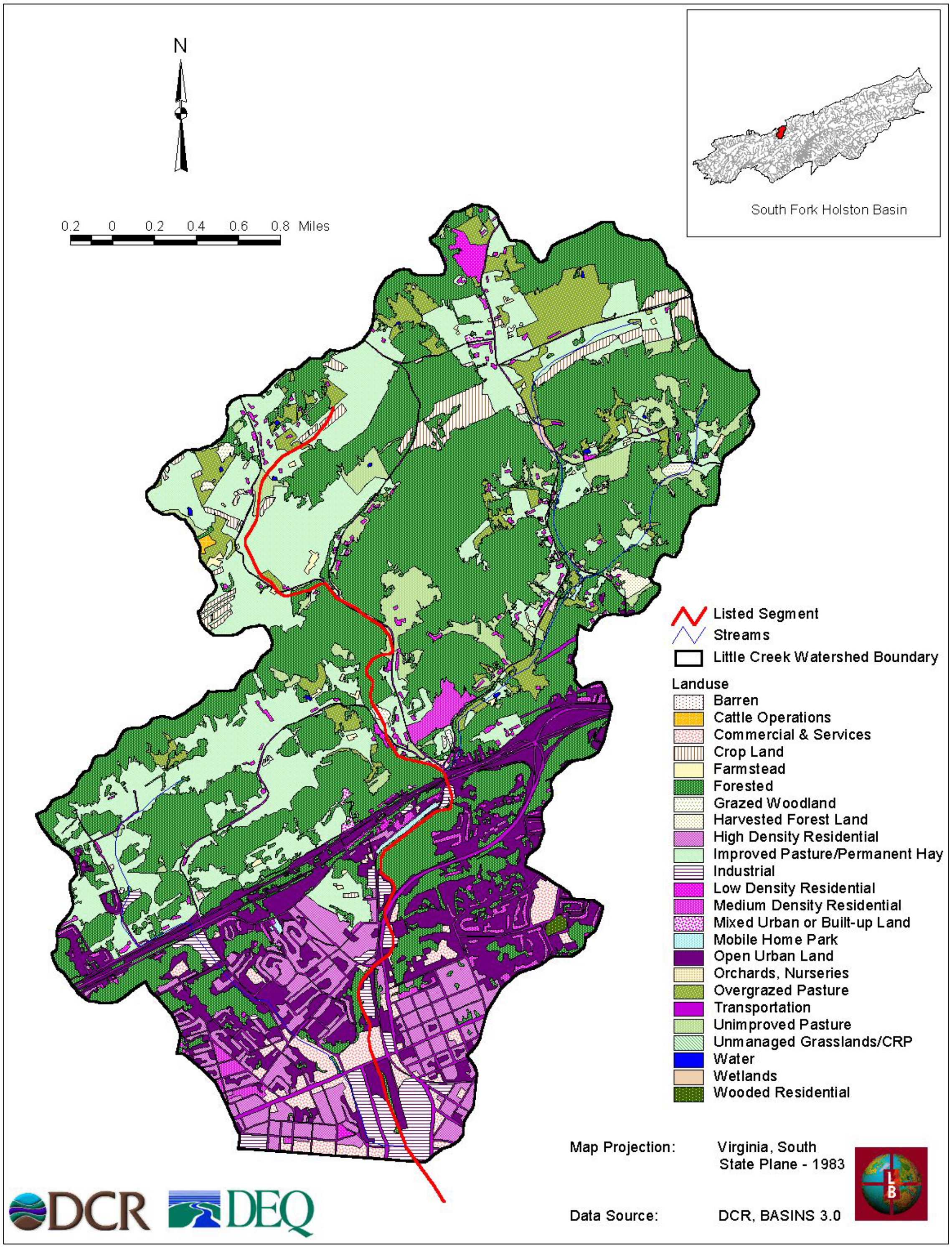
Land Use Type	Description
Barren	All types of barren land, including rock, beaches, strip mines, and bare transition areas, but not non-vegetated wetlands.
Cattle Operations	Confined cattle lots and confined dairy loafing lots. Fields that receive exceptionally heavy animal traffic, such as feed lots and areas located immediately adjacent to dairy barns. Cover can be very low to absent.
Commercial/ Services	Retail trade areas, wholesale service areas, and institutions. Includes all associated properties, such as yards and parking lots. Institutional land consists of educational, military, corrections, medical, religious, and government facilities.
Crop Land	All types of crop land except rotational hay.
Farmstead	Farm building "complexes", isolated farm buildings, storage sheds, and farm based residences. May include small diary animal waste containment facilities but not those large enough to be easily identified with 5m imagery.
Forest	All types of forest lands except those which have been harvested, those which are routinely grazed by farm animals, and those which are classified as forested wetlands.
Grazed Woodland	Wooded areas (> 50% canopy) that appear to allow livestock access.
Harvested Forest Land	Clear cut, spot harvested, and burnt forest lands.
High Density Residential	Row housing, garden apartments, and high-rise living units. Densities of more than 8 dwellings units/acre.
Improved Pasture	Pasture is good to very good coverage. May include "older" hayfields that are likely part of a less extensive row crop-hay rotation.
Industry	Manufacturing and industrial parks, including associated areas such as storage yards, parking lots, and tanks.
Low Density Residential	Detached single family/duplex dwelling units and their associated areas, such as yards, sheds, except those in large mostly wooded lots. Densities of .2 dwelling units/acre to 2 dwelling units/acre.
Medium Density Residential	Detached single family/duplex dwelling units, row housing, and their associated areas. Densities of 2 dwelling units/acre to 8 dwelling units/acre.
Mixed Urban or Built Up Land	Areas of mixed urban development other than mixed described as industrial/commercial complex mix, such as sites undergoing construction activity or some other type of urban transition.
Mobile Home Park	Mobile home and trailer parks. Trailers not in a mobile park are coded in accordance to the residential density as per above.
Open Urban Land	Urban areas not requiring structures and areas characterized by open land, particularly such lands within an urbanized area. Includes golf courses (but not rural golf courses), zoos, cemeteries, city parks, fair grounds, landfills, and other generally undeveloped urban uses dominated by porous surface areas.
Orchards, Nurseries	Orchards, groves, vineyards, nurseries, and ornamental horticulture areas. Includes Christmas tree farms.
Overgrazed Grassland	Pasture that has poor cover and signs of heavy animal traffic. Sometimes adjacent to loafing lots. Could include fields that have a lot of rock outcrops and shallow soils.
Transportation	Lands occupied by transportation such as airports, rail lines and yards, highways, and shipping ports. Also, communication uses such as towers and large satellite dishes, and utility uses such as electric, gas, water, and wastewater facilities.
Unimproved Pasture	Pasture land that appears to be less intensively managed in terms of brush/weed control, fertilizer applications, constructed water supplies and rotational grazing.
Unmanaged	Grasslands left unmanaged or set aside, such as those in the USDA Conservation Reserve

Land Use Type	Description
Grasslands/CRP	Program.
Water	All types of water features except those considered wetlands.
Wetlands	All types of wetlands, including forested wetlands and non-vegetated wetlands. Any wetland so identified in the National Wetland Inventory (NWI), but not the deepwater habitats of the NWI.
Wooded Residential	Individual units or tracts of residential units characterized by large, mostly wooded lots.

Source: DCR.

Figure 3-1 is a map showing the land use distribution in the watershed. The urban-related land uses are located in the lower part of the watershed, or south of I-81 in the City of Bristol, and the agricultural- and rural-related land uses are located in the upper part of the watershed, or north of I-81 in Washington County.

Figure 3-1: Land Use in the Little Creek Watershed



3.3 Stream Flow Data

Stream flow data for Little Creek do not exist; therefore an alternate station within the hydrologic unit was used in this TMDL development. Little Creek is a tributary of Beaver Creek; which has a stream flow gaging station in the City of Bristol. The data for Beaver Creek station was retrieved from the USGS and used in the model set-up, hydrological calibration, and the development of the fecal coliform TMDL.

3.4 Instream Water Quality Conditions

Water quality data for the Little Creek watershed was obtained from DEQ, the Tennessee Valley Authority, Tennessee Department of Environment and Conservation (TDEC) and water quality monitoring conducted by The Louis Berger Group, Inc. under contract with DCR.

Based on the sampling frequency, only one criterion is applied to a particular data set. If the sampling frequency is one sample per 30 days, the instantaneous criterion (1000 cfu/100ml) is applied; for higher sampling frequency, the geometric mean criterion (200 cfu/100 ml) is applied.

Table 3-5 lists the water quality sampling stations in the Little Creek watershed and provides a summary of the instream water quality conditions. Figure 3-2 is a map showing the locations of these water quality monitoring stations.

Little Creek station 6CLTL000.26 is located at the Virginia/Tennessee state line and is operated by DEQ. Sampling was completed on a monthly basis from 1971 to 1991, and again in 2001 and 2002. The fecal coliform data for this station shows a 73% violation of the fecal coliform standard.

The Tennessee Valley Authority operated five monitoring stations on Little Creek. These stations were located upstream of the state line and the stations monitored the water quality conditions in 1970. The data presented in Table 3-5 indicates that the water quality standard violation ranged from 0 to 100% for the 13 samples collected at these five stations.

The TDEC collected instream water quality samples in 1993, 1995, and 1996 at the same location as the DEQ station 6CLTL000.26. The data indicated that the fecal coliform concentration in the Little Creek exceeded the standard 100% of the time.

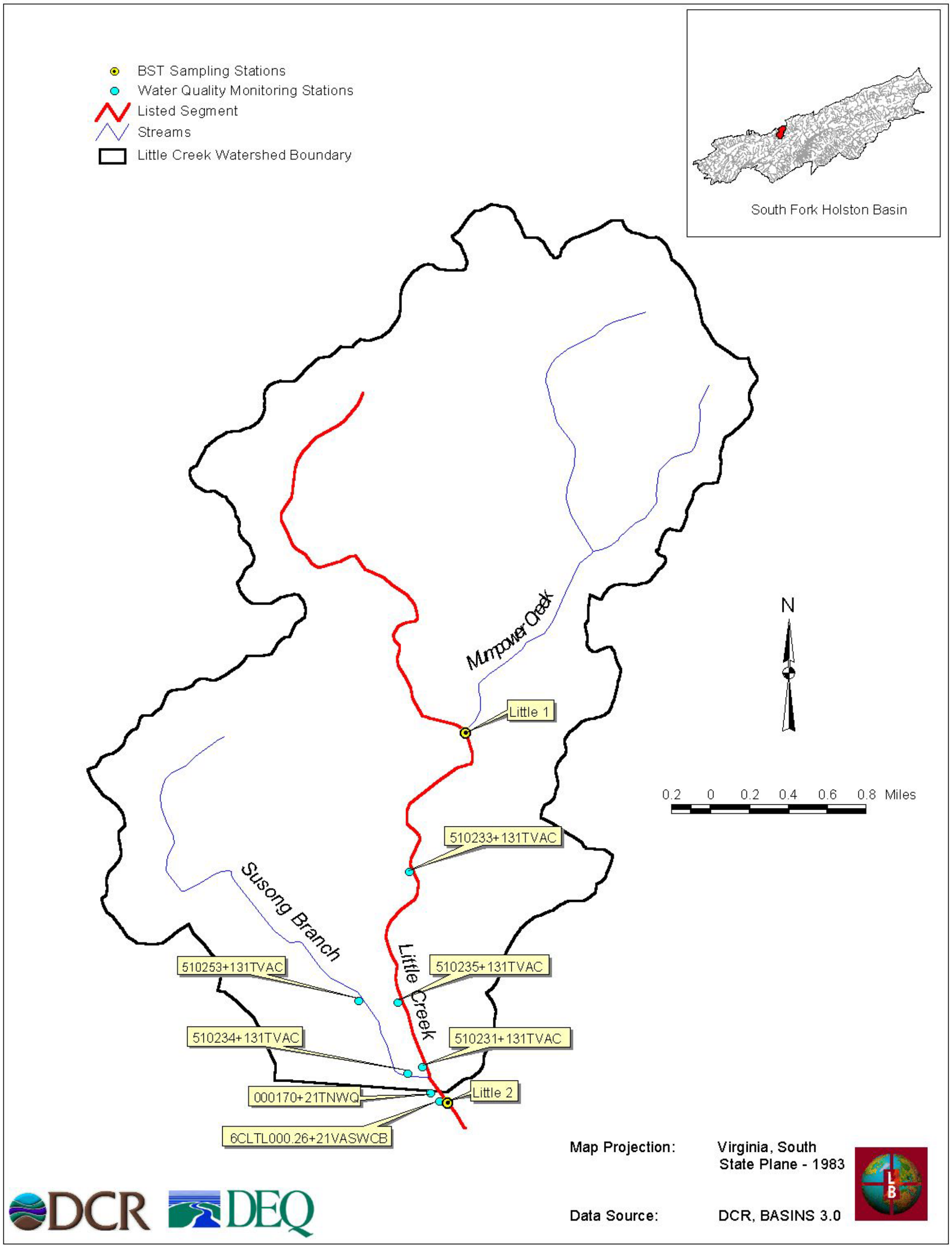
The Louis Berger Group, Inc. conducted water quality monitoring at two stations on Little Creek. Six monthly water quality samples were collected and enumerated. The data presented in Table 3-5 indicate that the water quality standard was violated 33% of the time at both stations.

Table 3-5: Summary of Water Quality Sampling Conducted in the Little Creek Watershed

Station Id	Period of Record	Number of Samples	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Violation[1] (%)
DEQ Stations						
6CLTL000.26	1971-2002	189	100	60,000	7,042	73
6CLTL001.28	2001-2002	4	100	400	175	0
6CMUN000.65	2001-2002	4	100	600	225	0
Tennessee Valley Authority Stations						
510233	1970	2	990	3,400	2,195	50
510235	1970	3	200	2,200	933	33
510231	1970	4	2,500	247,000	90,600	100
510234	1970	3	2,000	31,000	20,433	100
510253	1970	1	890	890	890	0
TDEC Stations						
Same as DEQ station 6CLTL000.26	1993-1996	30	460	200,000	17,341	100
The Louis Berger Group, Inc. Stations						
Little 1	2001-2002	6	190	1300	816	33
Little 2	2001-2002	6	250	1100	668	33

1: Based on the sampling frequency, only one criterion is applied to a particular data set. If the sampling frequency is one sample per 30 days, the instantaneous criterion (1000 cfu/100ml) is applied; for higher sampling frequency, the geometric mean criterion (200 cfu/100 ml) is applied.

Figure 3-2: Little Creek Watershed Water Quality Monitoring Stations



3.4.1 Bacteria Source Tracking

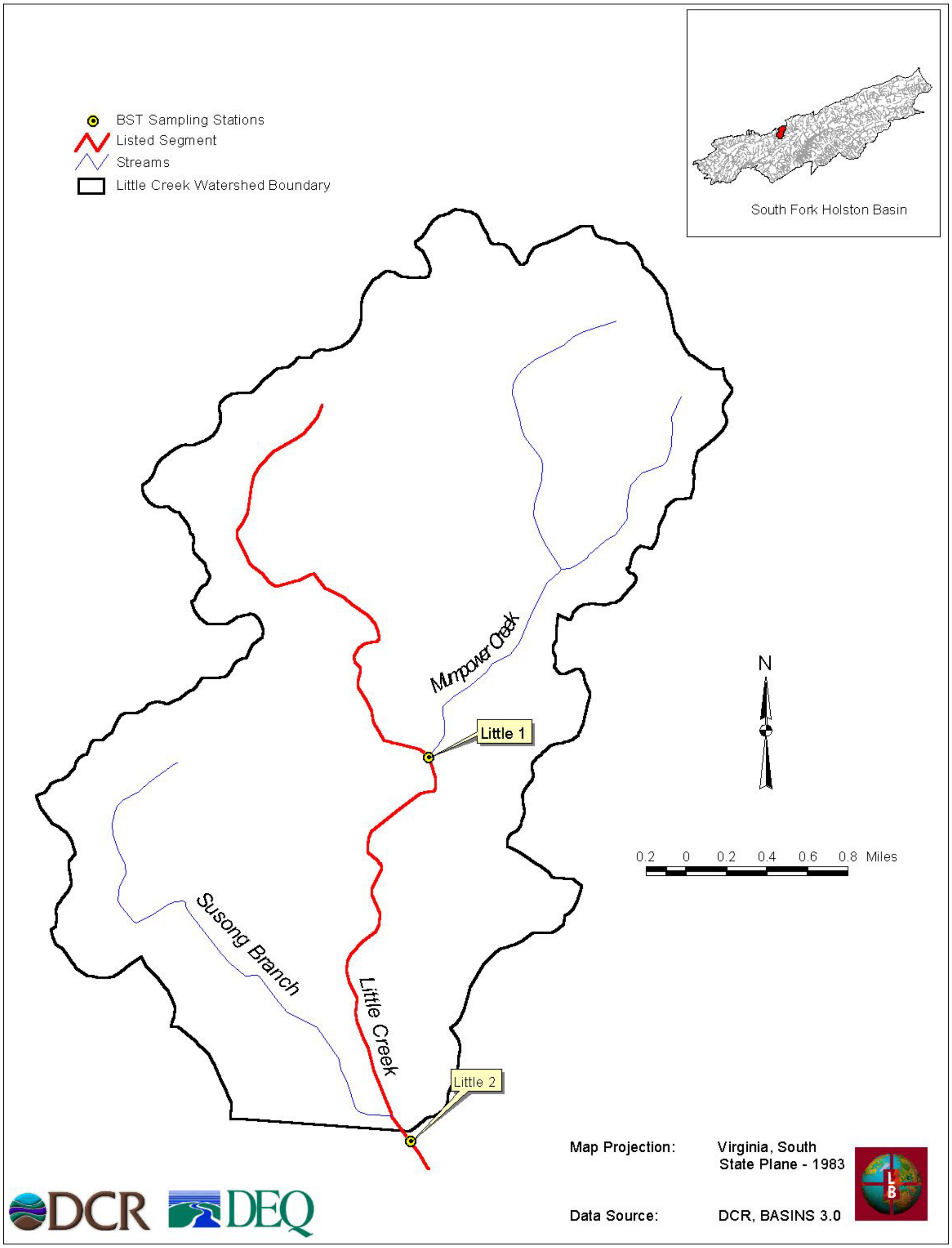
As part of the Little Creek TMDL development, The Louis Berger Group, Inc. contracted Map Tech, Inc. to conduct instream sampling and analysis of fecal coliform concentrations and bacteria source tracking (BST). The objective of BST was to identify the sources of fecal coliform in the listed segment of Little Creek. Subsequently, this information was used in the model set-up and in the analysis and distribution of the fecal coliform loading among the various sources, such as human, livestock, and wildlife.

There are various methods of performing BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are all referred to as "DNA fingerprinting" and are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria. Biochemical (phenotype) methods are based on an effect of an organism's genes that actively produce a biochemical substance. The type and quantity of these substances produced are what are actually measured. Chemical methods are based on finding chemical compounds that are associated with human wastewaters and would be restricted to determining sources of pollution as human or non-human.

For the Little Creek TMDL, the Antibiotic Resistance Analysis (ARA) method was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. ARA offers low cost per sample, fast turnaround times for analyzing samples, and ARA can be performed on large numbers of isolates: typically, 24 isolates per unknown source such as instream water quality sample. This provides measurements of the proportion of a given source that are in increments of approximately 4 percent.

In the Little Creek watershed, two sampling stations were set up and water quality samples were collected and analyzed on a monthly basis from September 2001 through February 2002. One station was located at the confluence of Little Creek and Mumpower Creek. The second station was located at the Virginia/Tennessee state line, which is the end of the Little Creek listed segment. Figure 3-3 is a map showing the location if the sampling stations on Little Creek.

Figure 3-3: Little Creek Watershed Bacteria Source Tracking



Four categories of sources were considered: human, wildlife, livestock, and pets. The BST results for six sampling events on a monthly basis at two stations located on Little Creek are presented in Table 3-6. The data indicate that fecal coliform bacteria from human, livestock, wildlife, and pets were present in Little Creek. The human signature ranged from 8 to 54%, the wildlife signature ranged from 0 to 42%, the livestock signature ranged from 13 to 38% and the pets signature ranged from 17 to 58%.

Table 3-6: Results of BST Analysis Conducted in the Little Creek Watershed

Location	Date	Fecal Coliform Concentration	Enterococci Concentration	No. of Isolates Analyzed	Percent of Enterococci Classified as			
		cfu/100 ml	cfu/100ml		Wildlife	Human	Livestock	Pets
Little 1	9/27/01	850	380	24	42%	17%	13%	28%
Little 1	10/17/01	1100	270	24	8%	13%	29%	50%
Little 1	11/13/01	190	300	24	33%	17%	21%	29%
Little 1	12/12/01	1300	860	24	33%	8%	33%	26%
Little 1	1/8/02	730	540	24	13%	21%	17%	49%
Little 1	2/5/02	730	140	24	13%	29%	38%	20%
Little 2	9/27/01	1000	600	24	21%	8%	17%	54%
Little 2	10/17/01	790	310	24	4%	54%	25%	17%
Little 2	11/13/01	250	400	24	42%	21%	21%	16%
Little 2	12/12/01	1100	900	24	42%	21%	21%	16%
Little 2	1/8/02	620	320	24	0%	8%	33%	59%
Little 2	2/5/02	250	120	24	0%	25%	21%	54%

3.5 Fecal Coliform Sources Assessment

This section will focus on characterizing the fecal coliform sources in the watershed that potentially can contribute to the fecal coliform loading to Little Creek. These sources include permitted sources, failed septic systems and straight pipes, livestock, wildlife, pets, and land application of manure and biosolids. Section 4.0 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

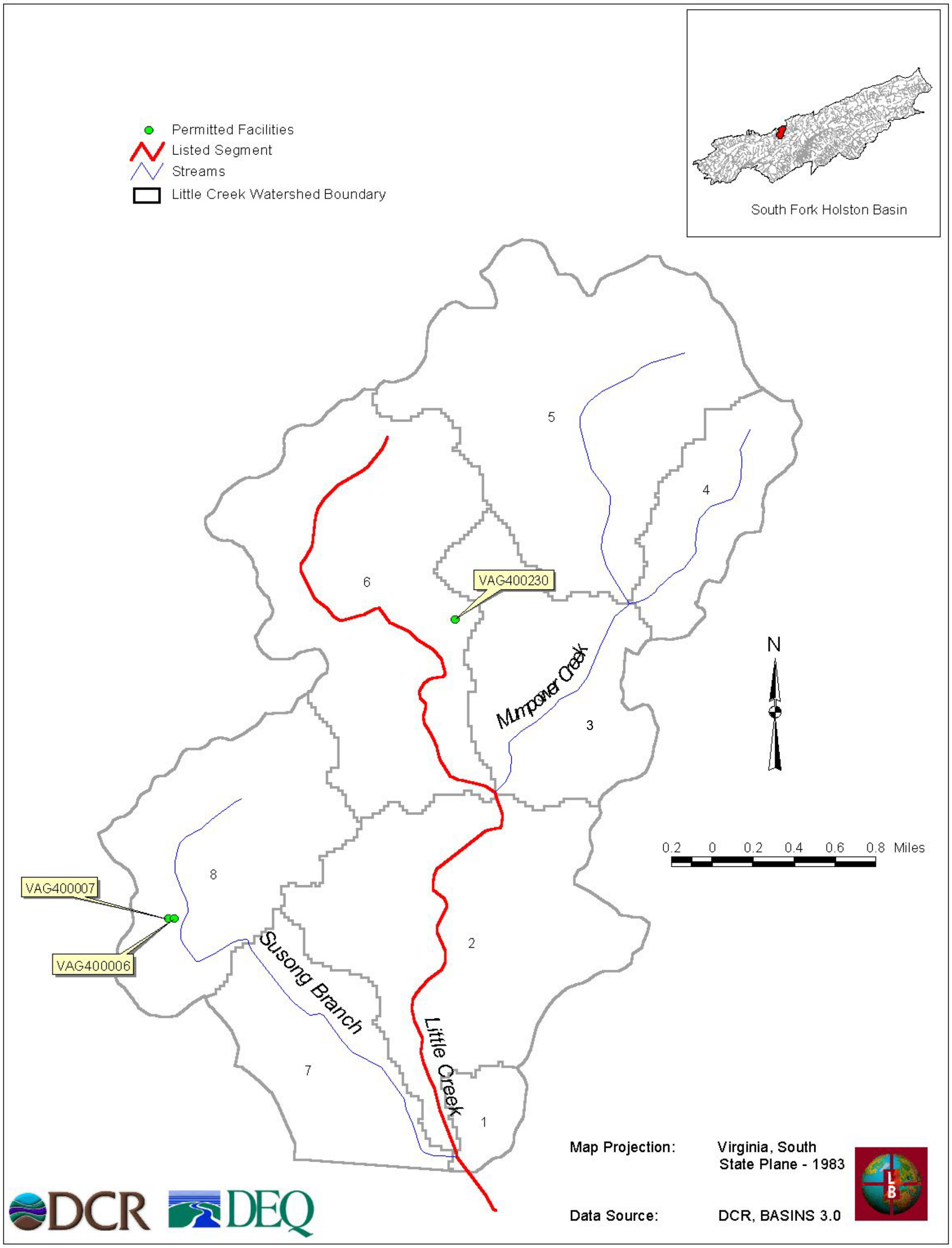
The DEQ's Southwest Regional Office provided data and information related to the three permitted facilities located in the Little Creek watershed. The permit number, facility name, design flow, and status of these facilities are presented in Table 3-7. Figure 3-4 is a map showing the locations of these permitted facilities.

Table 3-7: Permitted Dischargers in the Little Creek Watershed

VPDES ID	Permit Number	Facility Name	Design Flow (gpd)[1]	Status
VAG400007	6CXBT000.60	Harrell Duplex I STP	1000	Active
VAG400006	6CXBT000.55	Harrell Duplex II STP	1000	Active
VAG400230	6CMUM000.82	Shiloh Free Will Baptist Church	1000	New Facility

1. gpd: gallons per day

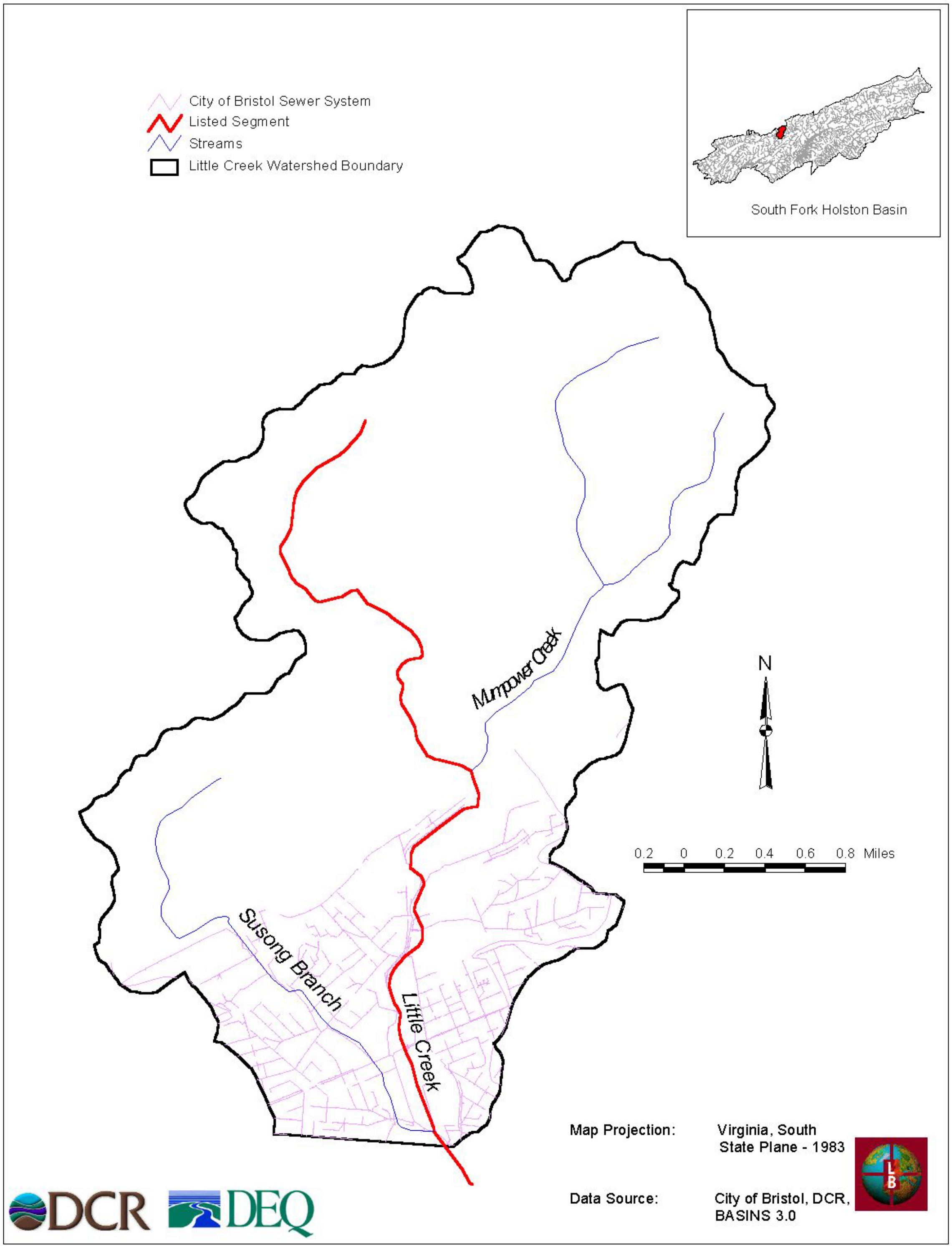
Figure 3-4: Location of Permitted Facilities



3.5.2 Sanitary Sewer Network

The City of Bristol provided extensive CAD drawings that show the extent of the sewer system in the area (Hurlbert, 2001). The extent of the sewer system in the Little Creek watershed is presented in Figure 3-5. The sewage collected in this network is conveyed to the wastewater treatment plant located in the Bristol, Tennessee. The sewer system does not extend north of the City of Bristol limits (I-81). The housing units north of I-81 are not served by a public sewer; therefore they rely on septic systems for the treatment of household waste.

Figure 3-5: Sewer Areas in Little Creek Watershed



3.5.3 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems was based on four sources of data:

- USGS 7.5 minute quadrangle maps,
- Washington County tax parcel data,
- City of Bristol CAD drawings, and
- U.S. Census Bureau data.

The City of Bristol provided sewer network maps in CAD drawings format. These drawings were converted to GIS layers and overlaid with the Little Creek watershed, Bristol City and Washington County boundaries. It was determined from these maps that the area of the watershed within the City of Bristol is served by a public sewer system and the area outside the city limits, which is within the Washington County jurisdiction, is served by septic systems.

The 1960 version of the Wallace and Bristol USGS 7.5 minute quadrangle maps were used to estimate the total number of housing units in the upper part of the watershed at 269.

Based on the tax parcel data obtained from Washington County, the total number of addressable structures in the area outside city limits was 459. An addressable structure is a structure with a U.S. Postal Service address.

The CAD drawings provided by the City of Bristol also contained structures. However, no data was available for classification into addressable or non-addressable structures. Therefore the CAD drawings of the structures were converted to GIS layers, overlaid with the tax parcel layers obtained from the Washington County and the watershed boundary. The maps showed that the total number of structures in the Little Creek watershed north of I-81 was 1,042 and about 50% of these structures are addressable and the remaining are not. Therefore, based on the combination of Bristol data and Washington County data, it was established that there are about 521 addressable structures outside the city limits (north of I-81).

In the upper part of the watershed where septic systems are the primary way to treat household wastewater, an estimated 404 housing units exist. This was based on the number of units estimated from the tax parcel data and assuming 82% occupancy. Furthermore, 269 of the 404 housing units have septic systems that are operational since 1960 based on the USGS topographic maps.

Based on CAD drawings of the sewer network and structures obtained form the City of Bristol, it was determined that approximately 1,568 total housing units are located in the Little Creek area within the City of Bristol Boundary. A public sewer serves these households.

In summary, the total number of house holds in the entire watershed was estimated at 1,972. This is comprised of 404 housing units on septic systems and 1568 housing units served by public sewer.

Review of the U.S. Census Bureau data for Washington County from 1960 to 2000 indicated the following:

- In 1960 the population was 38,076,
- In 2000 the population was 51,103,
- Between 1960 and 2000 the population increased by 34%,
- Between 1960 and 1980 population increased by 22%,
- Between 1980 and 1990 population increased by 9%, and
- Between 1990 and 2000 population increased by 11.4%.

For the same period the census data for the City of Bristol indicated the following:

- In 1960 the population was 17,144,
- In 2000 the population was 17,367,
- Between 1960 and 2000 the population increased by 1%,
- Between 1960 and 1980 population increased by 11%,
- Between 1980 and 1990 population **decreased** by 9%, and
- Between 1990 and 2000 population **decreased** by 6%.

It can be seen that the population growth patterns in Washington County and City of Bristol are extremely different. It is assumed that the population growth patterns of Bristol City will be more applicable than Washington County, as it is anticipated that no significant population growth will occur in the watershed within the next 5 to 10 years. This is based on the census data presented above, which showed that Bristol City area population has been declining since 1980 and 80% of the households are located within the City of Bristol boundary.

3.5.3.1 Failed Septic Systems

To determine the amount of fecal coliform contributed by human source, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rates were determined based on the total amount of septic systems versus the number of applications for new systems and the number of repairs for existing systems in Washington County. Table 3-8 shows the number of applications for new systems as well as the number of repairs over the last six years in Washington County. This data was combined with the population data to establish the rate for applications for new septic systems and the rate of failure for septic systems in the watershed. Table 3-9 shows the rate of applications for new septic systems in Washington County ranged from 1.9 to 3.1% from 1995 to 2000. For the same period, the data indicate that the rate of septic system repair permits ranged from 0.18 to 0.40%. These septic system failure rates are considered low for an area where septic systems have been operational since 1969. This low rate may be attributed to a large number of septic system repairs being performed without obtaining a permit.

A detailed discussion of the failure rates, flow, and fecal coliform concentration is presented in Section 4.

Table 3-8: Number of Applications for New Septic Systems and Number of Repairs in Washington County (including area outside the Little Creek Watershed)

Year	Applications for New Septic Systems	Repairs of Existing Systems
1995	591	76
1996	490	74
1997	586	73
1998	557	52
1999	419	37
2000	437	84
Average	**513**	**66**

Source: Scott Honaker, Per. Comm., November 19, 2001.

Table 3-9: Rates of Applications for New Septic Systems and Rates of Repairs in Washington County (including area outside the Little Creek Watershed)

Year	Total Households in Washington County	% New	% Repair
1995	18,960	3.1	0.40
1996	19,045	2.6	0.39
1997	20,679	2.8	0.35
1998	1,006	2.7	0.25
1999	21,098	2.0	0.18
2000	22,985	1.9	0.37

3.5.4 Livestock

An inventory of the livestock residing in the Little Creek watershed was conducted from data and information provided from the DCR nutrient management specialist, Holston River Soil and Water Conservation District, and field surveys. The data and information indicated that dairy and beef cattle are the predominant type of livestock. Other livestock includes horses, goats, and sheep. The inventory also indicates that there are no swine or poultry operations in the watershed. Table 3-10 summarizes the livestock inventory in the watershed.

Table 3-10: Little Creek Watershed Livestock Inventory

Livestock Type	Total Number of Animals
Beef Cattle	682
Dairy Cattle (total*)	300
Chicken	0
Swine	0
Horse	22
Goat	6
Sheep	3

*includes milked, dry cows and heifers

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. Table 3-11 displays the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-11: Daily Fecal Coliform Production of Livestock

Source	Daily Fecal Production (cfu/day)
Beef Cattle	3.3E+10
Dairy Cattle -Milked or dry Cow	2.52E+10
Dairy Cattle -Heifer	1.16E+10
Horse	4.20E+8
Goat	2.70E+10
Sheep	2.70E+10

Sources: ASAE, 1998; Metcalf and Eddy, 1979; Map Tech, Inc., 2000; EPA, 2001.

The impact of fecal coliform loading from livestock depends on whether the loading is directly deposited in the stream or indirectly deposited in the stream. For this analysis, the fecal coliform deposited while livestock are in confinement and while they are grazing was considered indirect. The fecal coliform from livestock directly defecated in the stream was considered direct. The distribution of the daily fecal coliform loading between direct or indirect is based on livestock daily confinement schedules. The directly deposited fecal coliform load from livestock was determined based on the amount of time livestock spends in the stream.

In the Little Creek watershed, it was determined that the only type of livestock that spends any time in confinement is dairy cattle. The other livestock do not spend any time in confinement. Table 3-12 shows the daily dairy cattle confinement schedule and the time spent in the stream and Table 3-13 shows the daily confinement schedule for beef cattle.

These confinement schedules were adapted from the Middle Blackwater River TMDL and presented during the Little Creek stakeholder meetings for review and comment.

Table 3-12: Daily Confinement Schedule for Dairy Cattle

Month	Time spent in		
	Pasture (Hours)	Stream (Hours)	Loafing Lot (Hours)
January	7.2	0.5	16.3
February	7.2	0.5	16.3
March	7.6	1.0	15.4
April	8.6	1.5	13.9
May	9.3	1.5	13.2
June	9.3	2.0	12.7
July	9.8	2.0	12.2
August	9.8	2.0	12.2
September	10.3	1.5	12.2
October	10.5	1.0	12.5
November	9.8	1.0	13.2
December	8.9	0.5	14.6

Table 3-13: Daily Confinement Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.0	1.0	0
February	23.0	1.0	0
March	22.5	1.5	0
April	22.0	2.0	0
May	22.0	2.0	0
June	21.5	2.5	0
July	21.5	2.5	0
August	21.5	2.5	0
September	22.0	2.0	0
October	22.5	1.5	0
November	22.5	1.5	0
December	23.0	1.0	0

3.5.5 Land Application of Manure

Land application of the manure that dairy cattle produce while in confinement is a typical agricultural practice. In the Little Creek watershed, the source of the manure for land application is from the only dairy farm in the watershed. This manure is applied to the croplands and some of the pasturelands in the watershed. Typical application rates are 6,000 gallons per acre for liquid manure and 10 tons per acre for solids (Gall, 2001).

3.5.6 Land Application of Biosolids

Nonpoint human sources of fecal coliform can be associated with the spreading of biosolids as a source of fertilizer and nutrients. There is no biosolid spreading in the Little Creek watershed; therefore it was not considered in development of the Little Creek TMDL (Turley and Gall, Per. Comm., November 2, 2001).

3.5.7 Wildlife

Similar to livestock contributions, fecal coliform contributions from wildlife can be both indirect and direct. Indirect sources are those that are carried from land areas of the watershed to the stream through rain and runoff events, where direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) DGIF harvest data and population estimates, and (3) stakeholder comments and observations.

Inventorying wildlife based on habitat availability was a starting point. The number of animals in the watershed was estimated using wildlife concentrations based on stream miles and buffer areas. Typical wildlife densities are presented in Table 3-14.

Table 3-14: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Goose	0.004 animals/acre	Within 66 feet of streams and ponds
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001.

The wildlife inventory presented in Table 3-15 was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-15: Little Creek Watershed Wildlife Inventory

Wildlife type	Number of Animals
Deer	215
Raccoon	117
Muskrat	514
Goose	22
Mallard	11
Wood duck	0
Wild Turkey	40

The wildlife inventory was used to determine the fecal coliform loading by wildlife in the watershed. Table 3-16 shows the average fecal coliform production per animal per day contributed by each wildlife type. The distribution of the wildlife daily fecal coliform load between direct or indirect was based on estimates of the amount of time each wildlife type spends on the land areas and in the stream. Table 3-16 also shows the percent of time each wildlife type spends in the stream on a daily basis.

Table 3-16: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Mallard	2,430	50
Wood Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.8 Pets

The contribution of fecal coliform loading from pets was examined in estimating the fecal coliform loading to Little Creek. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Little Creek watershed was estimated based on the number of households in the watershed assuming one dog and one cat per household. As previously, presented the total number of households in the watershed was estimated to be 1,972. Therefore there is a total of 1,972 cats and 1,972 dogs in the watershed.

Fecal coliform loading from pets occurs in residential areas of the watershed. The load was estimated based on the daily fecal coliform production rates of 504 cfu/day per animal for cats and 4.09 $x10^9$ cfu/day per animal for dogs.

3.6 Existing Best Management Practices

Information about the existing best management practices (BMPs) in the Little Creek watershed was compiled during interviews with the Natural Resources Conservation Service and DCR staff and was based on GIS data obtained from DCR. Table 3-17 is a list of the BMP types in the Little Creek watershed. These BMPs were not widely used in the watershed (only one BMP of each type was used); therefore the impact of these three BMPs on overall fecal coliform loading from the watershed would be negligible and was not included in the model.

Table 3-17: Existing Best Management Practices and Fecal Coliform Removal Efficiency

BMP	Description	Code	Number
Grazing Land Protection	This can include structural controls such as fencing and livestock watering systems. Rotational grazing can also be included. A livestock watering system can reduce the amount of time spent by each cow by 51 percent.	SL-6	1
Alternative Water Sources	This helps to keep livestock away from streams without using fencing or other types of structural BMPs.	SL-6B	1
Small Grain Cover Crop for Nutrient Management	Small grain cover crops for nutrient management are applied during winter months when no liquid dairy manure is applied to the field; therefore its removal efficiency would be zero.	SL-8B	1

Source: DCR, 2000.

4.0 Modeling Approach

This section describes the modeling approach used in the Little Creek TMDL development. The primary focus is on the sources representation in the model, assumptions used, the model calibration and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the waterbody that can:

- represent the watershed characteristics;
- represent the point and nonpoint sources of fecal coliform and their respective contribution;
- use input time series data (rainfall, and flow) and kinetic data (die-off rates of fecal coliform);
- estimate the instream pollutant concentrations and loadings under the various hydrologic conditions; and
- allow for direct comparisons between the instream conditions and the water quality standard.

4.2 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions of Little Creek under varying scenarios of rainfall and fecal coliform loading. The results from the developed Little Creek model have been used to develop the TMDL allocations based on the existing fecal coliform load.

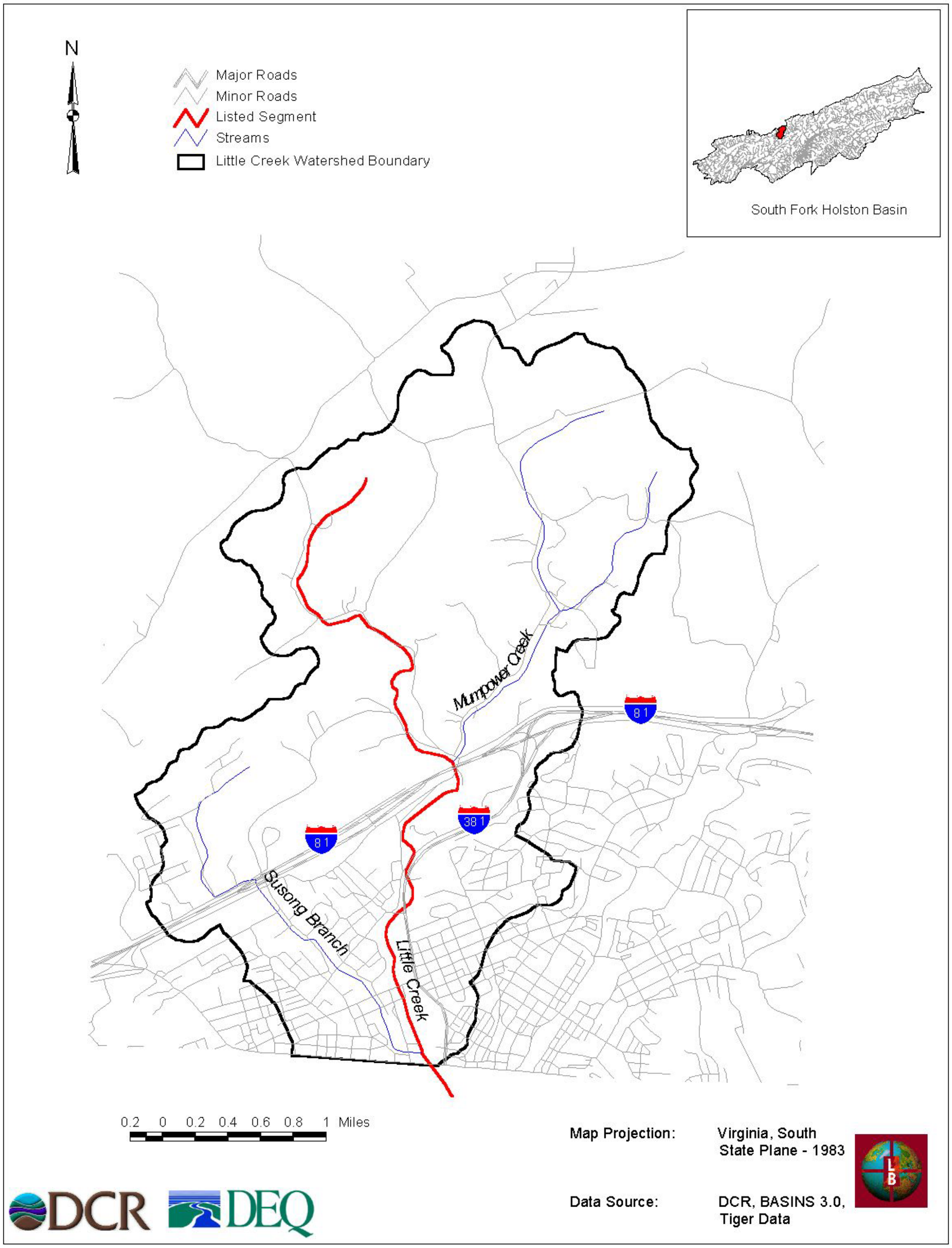
HSPF is a hydrologic watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with delineating the watershed into smaller subwatersheds then entering the physical data that describe each subwatershed and stream segment and entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loadings in the watershed. These processes are presented in the next few sections.

4.3 Watershed Boundaries

Little Creek is a tributary of the South Fork Holston River as part of the Tennessee Big-Sandy River Basin. The Little Creek watershed is approximately 5,520 acres or 8.64 square miles. The watershed is located in two jurisdictions: Washington County and the City of Bristol. Seventy percent of the watershed land area is located in Washington County and thirty percent of the watershed is located in the City of Bristol. Interstate Highway 81 (I-81), which runs through the watershed in a southwesterly direction, represents the dividing line between these two jurisdictions. The land area north of I- 81 is in Washington County and the land area south of I-81 is in the City of Bristol. Figure 4-1 is a map showing the location of the Little Creek Watershed.

Figure 4-1: Watershed Boundaries



4.4 Watershed Delineation

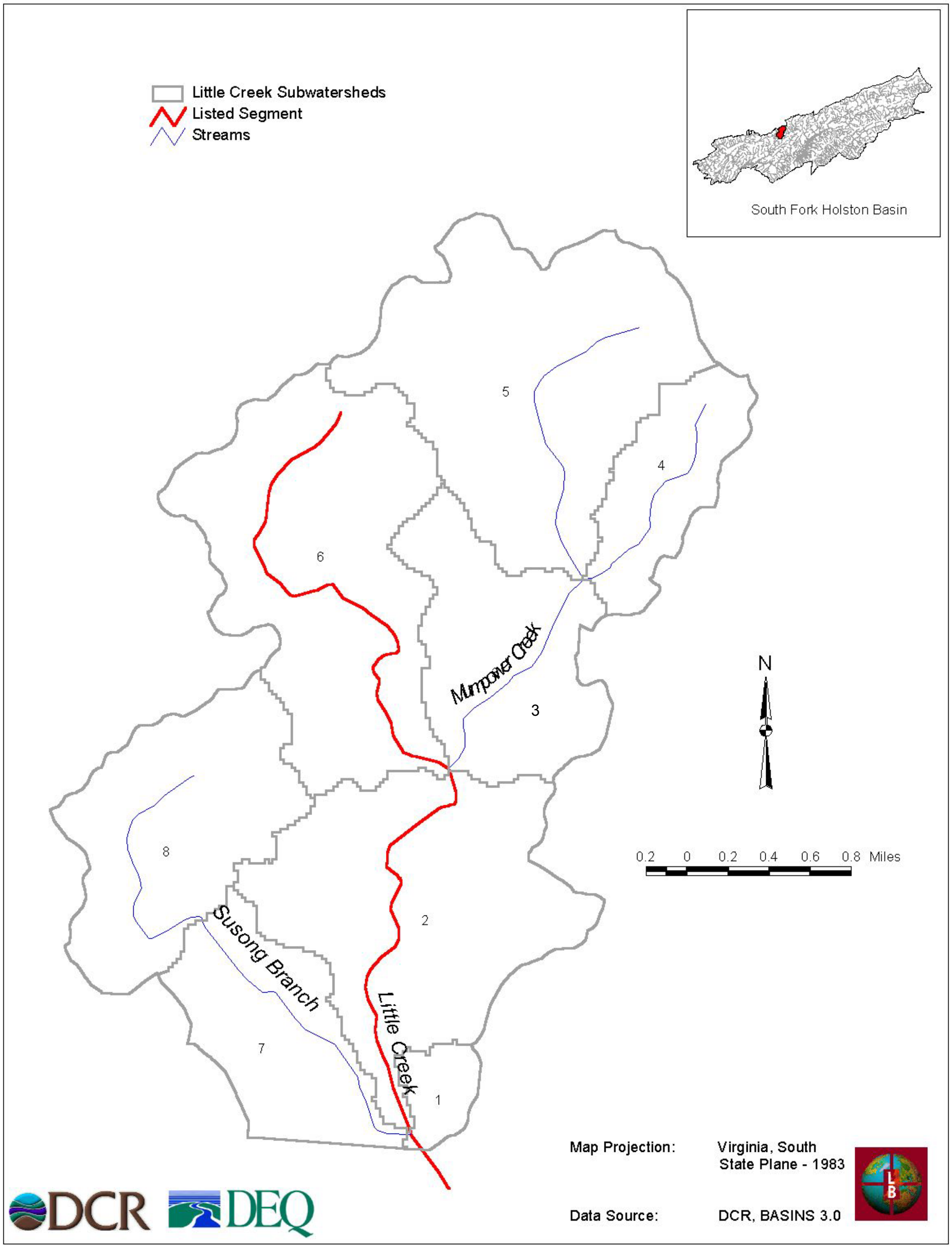
The Little Creek watershed was delineated into eight smaller subwatersheds to represent the watershed characteristics and to improve the HSPF model's accuracy. This delineation was based on the topographic characteristics using the Digital Elevation Model (DEM), the stream reaches using the RF3 data, and the location of stream flow and instream water quality monitoring stations. The areas of the eight subwatersheds are presented in Table 4-1. Figure 4-2 is a map showing the delineated watershed and subwatershed boundaries for Little Creek.

Subwatersheds 1, 2, 7 and part of 8 are located within the City of Bristol boundary and subwatersheds 3, 4, 5, and 6 are located within the Washington County boundary.

Table 4-1: Little Creek Delineated Subwatersheds

Watershed/Subwatershed	Drainage Area (acres)
1	100.39
2	1,030.51
3	591.13
4	326.85
5	1,150.18
6	1,125.43
7	487.21
8	708.35
Total	5,520.05

Figure 4-2: Little Creek Subwatershed Delineation



4.5 Land Use Reclassification

As previously mentioned, DCR developed the digital land use data for the Little Creek watershed and identified 32 land use classes. The land use data and the distribution in the Little Creek watershed were presented in Section 3.0. There are 24 land use classes in the Little Creek watershed, however the dominant land uses are forest, improved pasture and open urban lands. The original 24 land use types were reclassified to a representative number of land use types that best describe the Little Creek watershed conditions and the dominant fecal coliform source categories. The land use reclassification was based on similarities in hydrologic and potential fecal coliform production characteristics to meet the modeling goals and to facilitate model parameterization and reduce modeling complexity. The reclassified land use is presented in Table 4-2.

Table 4-2: Little Creek Land Use Reclassification

Reclassified Land Use	DCR Land Use Type	Acres	Percent
High Density Residential	High Density Residential, Mobile Home Park	315.80	5.72
Medium Density Residential	Medium Density Residential, Barren	80.40	1.46
Low Density Residential	Low Density Residential, Wooded Residential	77.53	1.40
Commercial/Industry	Commercial and Services, Industry, Transportation,	461.91	8.37
Other Urban	Transitional Urban, Open Urban Land, Mixed Urban or Built-up Land	570.13	10.33
Improved Pasture	Improved Pasture/Permanent Hay, Grazed Woodland	1133.15	20.53
Unimproved Pasture	Unimproved Pasture, Unmanaged Grassland	220.63	4.00
Overgrazed Pasture	Over Grazed Pasture, Cattle Operations	265.39	4.81
Crop	Crop Land, Orchards	97.45	1.77
Farmstead	Farmstead	13.59	0.25
Forest	Forested, Harvested Forest Land	2278.16	41.27
Wetlands	Wetlands	3.22	0.06
Water	Water	2.60	0.05
Total		5519.97	100.00

4.6 Hydrographic Data

Hydrographic data that describes the stream network and reaches were obtained from the Reach File Version 3 (RF3) contained in BASINS. This data was used for the HSPF watershed model and TMDL development. The reach number, reach name, and length are included in the RF3 database. Names of some reaches were added to the RF3 database using information from the USGS 7.5 minute quadrangle maps for Wallace and Bristol, Virginia. Table 4-3 provides a summary of the reach information for Little Creek.

Table 4-3: Little Creek RF3 Reach Information Summary

Reach Number	Reach Name	Length (miles)
6010102 270 0.00	Little Creek	0.33
6010102 270 0.33	Little Creek	2.14
6010102 270 2.45	Little Creek	2.68
6010102 271 0.00	Mumpower Creek	1.20
6010102 271 1.19	Unnamed Tributary	1.16
6010102 272 0.00	Unnamed Tributary	1.62
6010102 273 0.00	Susong Branch	2.87

The U.S. Army Corps of Engineers, Nashville District collected stream cross-sectional data during a floodplain study that focused on the Little Creek segment within the city limits. In addition to this data, the stream geometry was field surveyed for representative reaches of Little Creek. The stage flow relationship that is required by HSPF was developed based on the USGS stream flow gage data for Beaver Creek. The relationship was then transferred to the Little Creek watershed based on the drainage area weighted method to determine the function tables (F-Tables) for the eight stream segments.

Little Creek and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation and assuming a roughness coefficient of 0.05.

Model representation of the Little Creek stream reach segments is presented in Appendix A.

4.7 Fecal Coliform Sources Representation

This section will show how the fecal coliform sources identified in Section 3.0 were included or represented in the model. These sources include permitted sources, failed septic systems and straight pipes, livestock, wildlife, pets, and land application of manure. The loadings from individual sources were calculated and numbers are presented in Appendix B.

4.7.1 Permitted Facilities

The DEQ Southwest Regional Office identified the three permitted facilities in the Little Creek watershed. Table 4-4 shows the permit number for each facility, the stream reach receiving the discharge, and the facility discharge rate, fecal coliform concentration in the discharge and the status of the facility.

In the HSPF model, all of the permitted facilities were represented as a constant source, discharging 1,000 gallons per day at a fecal coliform concentration of 200 cfu/100 ml.

Table 4-4: Permitted Dischargers in the Little Creek Watershed

VPDES ID	Receiving Stream Reach	Flow (gpd)[1]	Fecal Coliform Concentration (cfu/100ml)	Status
VAG400007	Susong Branch	1000	200	Active
VAG400006	Susong Branch	1000	200	Active
VAG400230	Little Creek	1000	200	New Facility

1. gpd: gallons per day

4.7.2 Sanitary Sewer Network

The City of Bristol provided extensive CAD drawings that showed the extent of the sewer system in the area (Hurlbert, 2001). The sewage collected in this network is conveyed to the sewage treatment plant located in City of Bristol, Tennessee. Therefore the discharge from the sewage treatment plant was not included in this TMDL since it occurs outside the watershed boundary.

4.7.3 Failed Septic Systems

Failed septic system loading into Little Creek can be direct (point) or land-based (indirect or nonpoint) depending on the proximity of the septic system to the stream. In cases where the septic system is within the 20-foot stream buffer, the failed septic system was represented in the model similar to a permitted facility.

As explained in Section 3.0, the total number of septic systems in the watershed was estimated at 404 systems and it was determined that 269 of these septic systems have been operational since 1960.

Based on GIS data, only 4 of the 404 or about 1 percent of the homes on septic systems are located in the 20-foot stream buffer. Not all septic systems located within the stream buffer are considered failed systems, so only a fraction of the 4 systems were included in the model as straight pipes. The remaining failed septic systems were considered land-based source.

It was also established that the reported septic system repair rate was low relative to the age of the households in the watershed. Based on a study by Raymond Reneau of Virginia Tech (DCR, 2001), typical failure rates are:

- about 40% for septic systems in place prior to 1964;
- about 20% for septic systems in place between 1964 and 1984; and
- about 5% for septic systems in place post-1984.

For this TMDL development, it was assumed that an overall 10% failure rate for systems installed since 1960s and an overall 5% failure rate for systems installed post-1984 would be representative of the watershed conditions. To account for uncontrolled discharges in the watershed, the number of straight pipes was estimated as 0.5% of the septic systems installed in 1960. Table 4-5 shows the number of septic systems per subwatershed used in the model.

Table 4-5: Failed Septic Systems and Straight Pipes Assumed in Model Development

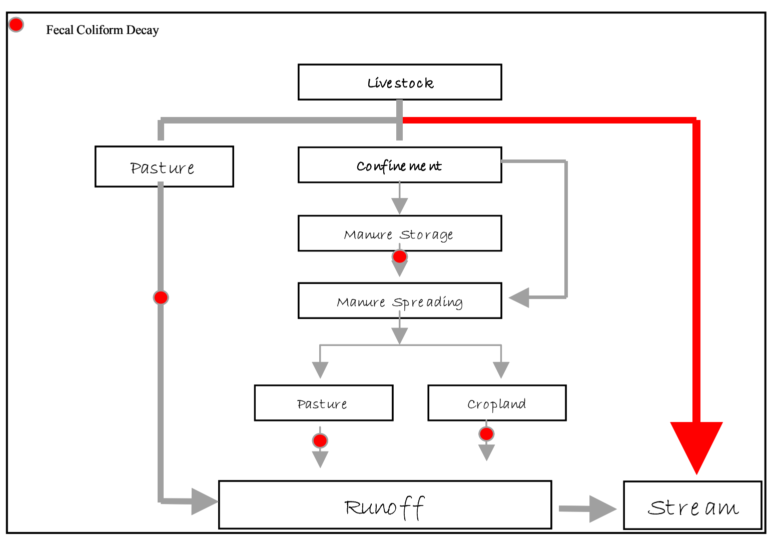
Subwatershed ID	Number of Septic systems since 1960	Number of septic systems post-1984	Number of Failed Septic Systems	Number of straight pipes
1	0	0	0	0
2	5	5	1	0
3	27	84	7	0
4	18	11	2	0
5	93	0	9	1
6	86	1	9	0
7	0	0	0	0
8	40	34	6	0
Total	**269**	**135**	**34**	**1**

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems design flow of 75 gallons per capita per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations (DCR, 2001).

4.7.4 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in Figure 4-3. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock is in confinement and later

Figure 4-3: Livestock Contribution to Little Creek Watershed



spread onto the crop and pasture lands in the watershed (land application of manure), and finally, the land-based fecal coliform deposited by livestock while grazing.

Based on the inventory of the livestock in Little Creek, it was determined that dairy and beef cattle are the predominant types of livestock. Other livestock, like horses, goats, and sheep, were identified in the watershed. The inventory also indicated that there are no swine or poultry operations in the watershed.

The distribution of the daily fecal coliform load between direct instream and indirect (land-based) loading was based on the livestock daily confinement schedules. In the Little Creek watershed, it was determined that the only type of livestock that spends any time in confinement is dairy cattle. The other livestock do not spend any time in confinement. The monthly direct and indirect fecal coliform loading is presented in Appendix B.

The direct deposition load from livestock was estimated based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the fraction of time livestock spend in the stream. The amount of time livestock spend in the stream was presented in Section 3.0.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends on the pasturelands.

The fecal coliform deposited while in confinement is collected and later spread on crop and pasture lands in the watershed. This type of loading will be addressed in the next section.

4.7.5 Land Application of Manure

Land application of the manure that dairy cattle produce while in confinement is a typical agricultural practice. In the Little Creek watershed, only one dairy farm was identified that practices the spreading of manure on crop and pasture lands. The loading from land application of manure was estimated based on the total number of dairy cattle in the watershed, the fecal coliform production per animal per day, and percent of the time the cattle spend in confinement. The manure will be applied to the croplands and some of the pasturelands in the watershed. Typical application rates are 6,000 gallons per acre for liquid manure and 10 tons per acre for solids (Gall, 2001). However, the dairy farm does not have a manure storage facility, therefore the manure is scraped and applied to the croplands and pasturelands in the watershed on a daily basis. The distribution of the produced manure was 75% cropland and 25% pastureland. The monthly loading rates to cropland and pasture lands are presented in Appendix B.

4.7.6 Land Application of Biosolids

There is no land application of biosolids in the Little Creek watershed, therefore it was not considered in development of the Little Creek TMDL (Turley and Gall, Per. Comm., November 2, 2001).

4.7.7 Wildlife

The fecal loading from wildlife was estimated the same way the loading from livestock was calculated and presented in Appendix B. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. Indirect sources are those that are carried from land areas of the watershed to the stream through rain and runoff events, where direct sources are those that are directly deposited into the stream.

The distribution of the daily wildlife fecal coliform production into a direct (land-based) load was based on the amount of time each wildlife type spends in the stream. In the wildlife inventory (Section 3.0), the daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented. The direct fecal coliform load from wildlife was calculated as the product of the number of each wildlife type in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends in the stream. The indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the wildlife number in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on the land areas in the Little Creek watershed. The resulting fecal coliform loading was then distributed on forest, pasture, cropland uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre) then by multiplying by the total area of pasture, crop land, and forest in each subwatershed.

4.7.8 Pets

For the Little Creek TMDL, the pet fecal coliform loading was considered a land-based load that is primarily deposited in the residential areas in the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per pet type. The monthly loading of fecal coliform to the residential land uses is presented in Appendix B.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Little Creek watershed. Three fecal coliform die-off rates required by the model to accurately represent the conditions in the watershed are:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure and litter is in-storage facilities.
2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.
3. **Instream fecal coliform die-off**. Fecal coliform directly deposited into the stream as well as fecal coliform that enters the stream from indirect sources will undergo decay.

In the Little Creek TMDL, no in-storage die-off was included in the model since there are no manure storage facilities located in the Little Creek watershed. A fecal coliform decay rate of 1.366 per day was used to represent the on-surface fecal coliform die-off. Finally, the instream fecal coliform die-off rate of 1.152 per day was used (EPA, 1985 and EPA, 2001).

4.9 Model Set-Up, Calibration and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) to make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process involves comparing the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process involves comparing the model output to the observed data set, which is different from the one used in the calibration process, and estimating the model's prediction accuracy. The hydrologic and the water quality components of the model will be calibrated. The hydrologic processes of the model were calibrated prior to the water quality processes calibration.

4.9.1 Model Set-Up

The HSPF model was set up and calibrated based on the Beaver Creek flow data and watershed characteristics, because there were no available stream flow data for Little Creek. Little Creek is a tributary of Beaver Creek, therefore these watersheds are hydrologically similar. The hydrologic similarity between the two watersheds was established based on the land use conditions and soil types.

The Beaver Creek national land cover data (NCLD) was retrieved from the USGS. The NCLD is GIS data in a grid GIS format. The data was projected, clipped and converted to GIS shape files, and characterized prior to comparing them with the Little Creek land use data. The land uses in Beaver Creek and Little Creek watersheds were divided into three categories: urban, non-urban, and other land uses. Table 4-6 shows these categories and the land use distribution in each category for the two watersheds. The non-urban land uses category that includes forest, pasture and cropland areas account for 89% of the Beaver Creek watershed and 72% of the Little Creek watershed. The urban land use category that includes the residential, commercial, industrial and transportation services areas accounts for 10% of the Beaver Creek watershed and 28% of the Little Creek watershed. The land use distribution indicates that the Little Creek watershed is slightly more urban influenced than the Beaver Creek watershed. This is primarily because of the presence of I-81 and the City of Bristol within the watershed boundary.

Table 4-6: Comparison of Land Use Distributions between Beaver Creek and Little Creek

Category	Land Use	Beaver Creek		Little Creek	
		Acre	%	Acre	%
Non-Urban land uses	Forest	9,029.7	50.9	2,278.2	41.3
	Pasture/Hay	6,356.8	35.8	1,619.2	29.3
	Row Crops	473.8	2.7	96.0	1.7
	Total Non-Urban land uses	**15,860.3**	**89.4**	**3,993.4**	**72.3**
Urban Land Uses	High Intensity Residential	69.9	0.4	308.2	5.6
	Low Intensity Residential	1,043.8	5.9	177.6	3.2
	Open Urban	13.8	0.1	565.1	10.2
	Other Urban	122.3	0.7	6.5	0.1
	Commercial/Industrial/ Transportation	552.0	3.1	463.3	8.4
	Total Urban land uses	**1,801.7**	**10.1**	**1,520.8**	**27.6**
Other Land uses	Wetlands	53.8	0.3	3.2	0.1
	Water	41.2	0.2	2.6	0.0
	Total Other Land uses	**95.0**	**0.5**	**5.8**	**0.1**
Total for entire watershed		**17,757.0**	**100**	**5,520.0**	**100**

Comparison of the difference between the percentages of pervious and impervious land uses in the two watersheds was also performed to confirm the hydrologic similarities between the watersheds. For each land use, the percent impervious area directly connected to the stream is presented in Table 4-7. The corresponding number of acres in Beaver Creek and Little Creek watersheds was calculated for each land use and presented in Table 4-8. The table indicates that the percent pervious in Beaver Creek was 99.4 percent compared to 98.7 percent for Little Creek. The impervious areas in Beaver Creek was 0.6 percent compared to 1.3 percent in Little Creek. This shows that overall the land use conditions in Beaver Creek and the Little Creek watersheds are considered similar.

In addition to land use, soil distribution in the watersheds was analyzed. The Frederick-Carbo-Timberville soils series is present in Beaver Creek and Little Creek watersheds. This is a well-drained soil and based on the hydrologic soil group classification. This soil series ranges from B to C.

Based on the land use data and the soil distribution, the Beaver Creek watershed is hydrologically similar to Little Creek watershed. Therefore, the Beaver Creek watershed with the sufficient data was used to set up and calibrate the HSPF model and was used in the fecal coliform TMDL development in the Little Creek watershed.

Table 4-7: Percent Imperviousness by Land Use

Land use	Impervious areas directly connected to streams (percent)
Low Intensity Residential	5
Improved Pasture/Hay	0.5
Row Crops	0.5
Medium Intensity Residential	5
Unimproved Pasture	0.5
Commercial/Industrial/Transportation	2.5
Open Urban	5
Farmstead	1

Table 4-8: Comparison the Imperviousness of Beaver Creek and Little Creek

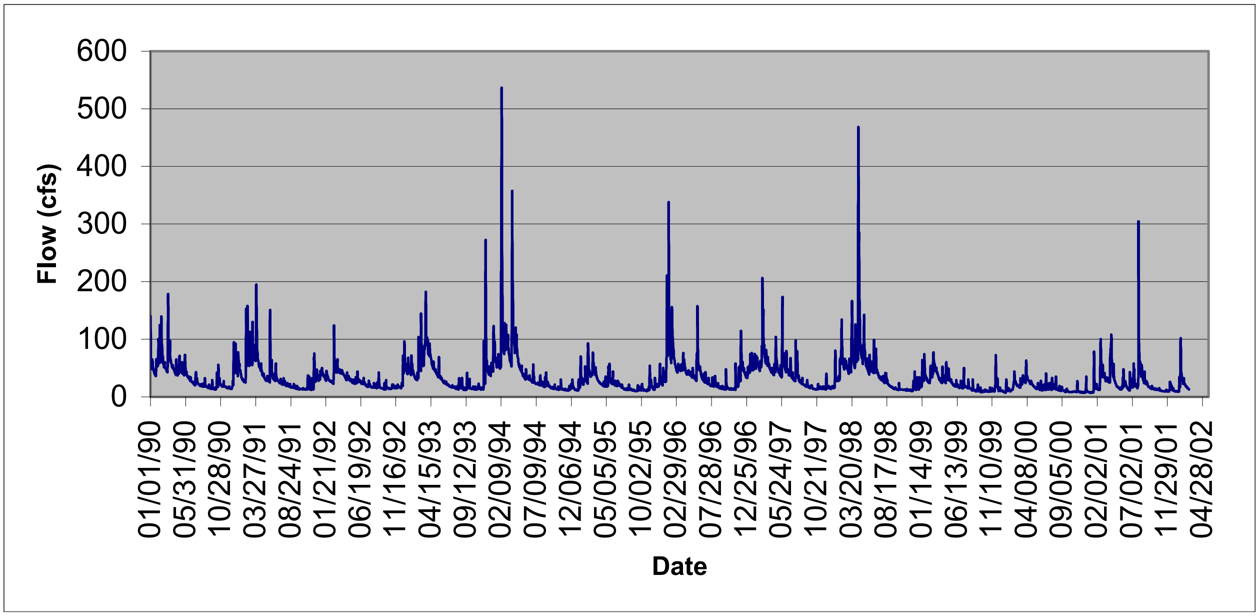
Land Use	Beaver Creek			Little Creek		
	Acre	Imper-vious	Pervious	Acre	Imper-vious	Pervious
Forest	9,029.70	0.00	9,029.70	2,278.20	0.00	2,278.20
Pasture/Hay	6,356.80	31.78	6,325.02	1,619.20	8.10	1,611.10
Row Crops	473.8	2.37	471.43	96	0.48	95.52
High Intensity Residential	69.9	3.50	66.41	308.2	15.41	292.79
Low Intensity Residential	1,043.80	52.19	991.61	177.6	8.88	168.72
Open Urban	13.8	0.69	13.11	565.1	28.26	536.85
Other Urban	122.3	6.12	116.19	6.5	0.33	6.18
Commercial/Industrial/ Transportation	552	13.80	538.20	463.3	11.58	451.72
Total for watershed (acres)	**17,662.10**	**110.44**	**17,551.66**	**5,514.10**	**73.03**	**5,441.07**
Total for watershed (Percent)		**0.6%**	**99.4%**		**1.3%**	**98.7%**

4.9.2 Stream Flow Data

Stream flow data for Little Creek do not exist, therefore, the data from Beaver Creek at Bristol USGS station ID 03478400, was used in this TMDL development. The Beaver Creek stream flow station at Bristol has a period of record from 1957 to 2002. The average flow data for the period from 1990 to 2002 was retrieved and plotted in Figure 4-4. The average flow of Beaver Creek ranged from 7.1 to 534 cfs with an average flow of 32.8 cfs.

The retrieved stream flow data from this station was used in the set-up and calibration of the hydrological process of the HSPF model for Beaver Creek. The calibrated Beaver Creek model was directly applied to the Little Creek watershed since Little Creek is a tributary of Beaver Creek. Only parameters that describe the physical conditions of Little Creek and the watershed were adjusted. None of the HSPF model hydrologic calibration parameters were adjusted while transferring the calibrated model.

Figure 4-4: Daily Mean Flow (cfs) at USGS Station ID 03478400



The continuous stream flow data from the USGS gaging station located on Beaver Creek (USGS 03478400) in Bristol has recorded daily flow data since October 1, 1957. The data were obtained from the USGS website (www.usgs.gov) and used in the model calibration and validation. A five-year period (1993-1998) was selected as the calibration period for the Beaver Creek model.

4.9.3 Rainfall and Climate Data

Weather data for Bristol WSO Airport, TN were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Bristol airport recorded data from 1948 to 2002. These hourly data were directly inputted into the HSPF model.

4.9.4 Model Hydrologic Calibration Results

The HSPEXP, an expert system software (Lumb and Kittle, 1993), was used to calibrate the HSPF model for the Beaver Creek watershed. After each iteration of the model run, HSPEXP calculates certain statistics and compares the model results with observed values to provide guidance on parameter adjustment according to the built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended criteria in HSPEXP as target values for an acceptable hydrologic calibration, the Beaver Creek calibration results are presented in Table 4-9. The table shows the simulated and observed daily average flow values for nine flow characteristics. The error statistics summary for seven flow conditions for the calibration is presented in Table 4-10. The breakdown of the overall percent base, storm and interflow contributions is presented in Table 4-11. The model results and the observed daily average flows at Beaver Creek are plotted in Figure 4-5.

Table 4-9: Beaver Creek Calibration Results

Category	Simulated	Observed
Total annual runoff, in inches	171.50	163.60
Total of lowest 50% flows, in inches	47.25	47.75
Total of highest 10% flows, in inches	40.60	38.94
Total storm volume, in inches	4.64	4.31
Average of storm peaks, in cfs	62.11	67.80
Base flow recession rate	0.96	0.96
Summer flow volume, in inches	34.72	30.96
Winter flow volume, in inches	56.67	50.80
Summer storm volume, in inches	1.11	0.98

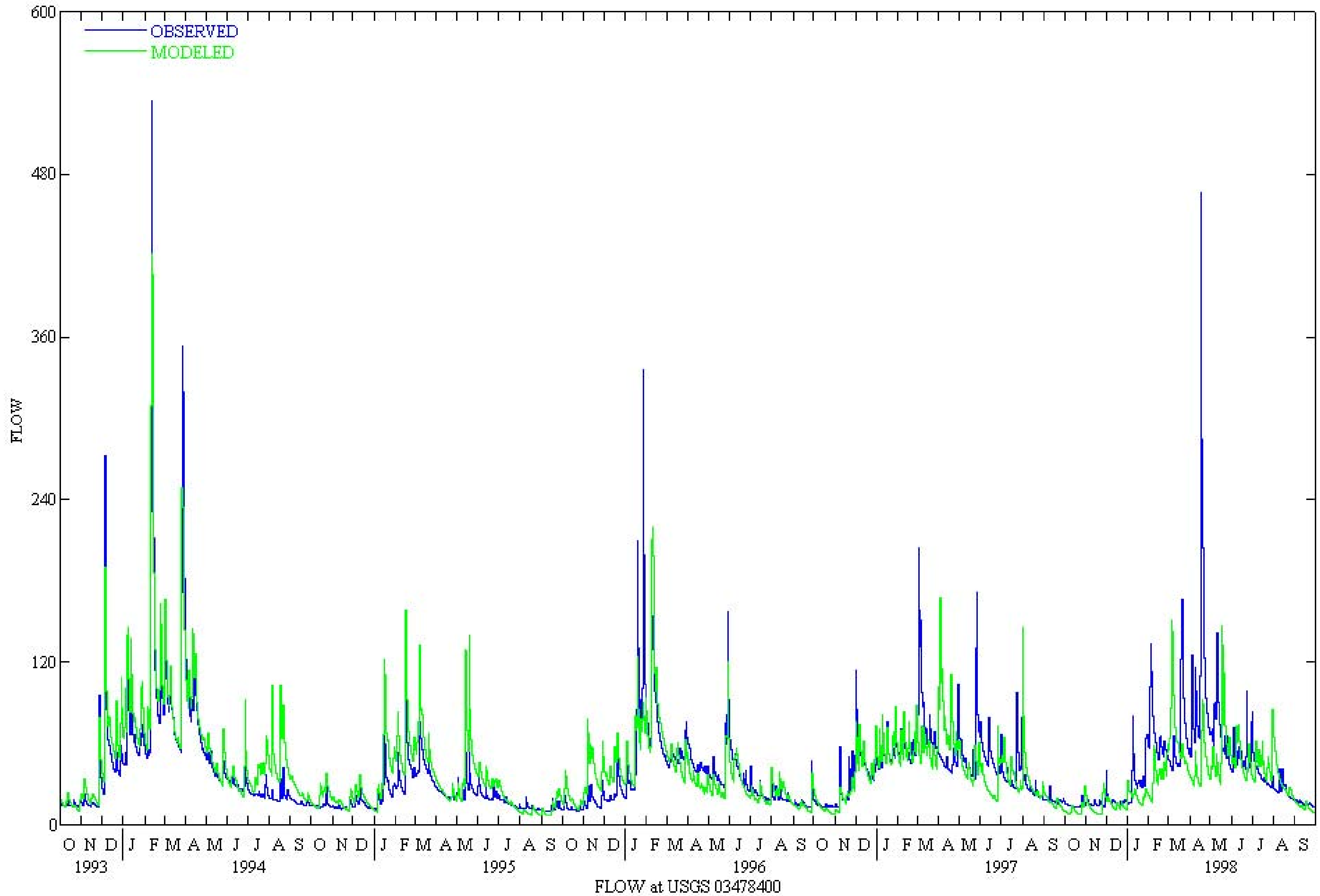
Table 4-10: Beaver Creek Calibration Error Statistics

Category	Current	Criteria
Error in total volume	4.80	10.00
Error in low flow recession	0.00	0.01
Error in 50% lowest flows	4.30	10.00
Error in 10% highest flows	-1.00	15.00
Error in storm volumes	-8.40	-15.00
Seasonal volume error	0.50	10.00
Summer storm volume error	5.50	15.00

Table 4-11: Beaver Creek Simulation Water Budget

Year	Surface Runoff (inches)	Interflow (inches)	Base flow (inches)	Surface runoff	Interflow	Base flow
1993	0.99	3.17	14.6	5.27%	16.90%	77.83%
1994	2.79	6.18	17.3	10.62%	23.52%	65.85%
1995	1.46	3.03	13.3	8.21%	17.03%	74.76%
1996	0.95	2.85	14.7	5.12%	15.41%	79.47%
1997	1.41	3.11	13.2	7.96%	17.55%	74.49%
Average				7.44	18.08	74.48

Figure 4-5: Beaver Creek- HSPF Model Hydrologic Calibration Results



4.9.5 Model hydrologic Validation Results

The period from October 1998 to September 2000 was used to validate the HSPF model. The validation results are presented in Figure 4-6 and the summary statistics from HSPEXP are presented in Table 4-12 and Table 4-13. The error statistics indicate that the validation results were within the recommended ranges in HSPEXP except for the seasonal volume error. In particular the winter flow was underestimated. This may be the result of a number of factors, such as the lack of major rainfall events during this period, the presence of the reservoir in the watershed and difficulty in simulating winter conditions. The breakdown of the overall percent base-, storm- and interflow contributions is presented in Table 4-14.

Table 4-12: Beaver Creek Validation Results

Category	Simulated	Observed
Total annual runoff, in inches	41.580	39.408
Total of lowest 50% flows, in inches	8.410	8.991
Total of highest 10% flows, in inches	11.660	12.234
Total storm volume, in inches	0.920	0.924
Average of storm peaks, in cfs	38.451	36.800
Base flow recession rate	0.970	0.950
Summer flow volume, in inches	9.260	8.899
Winter flow volume, in inches	12.520	9.174
Summer storm volume, in inches	0.370	0.330

Table 4-13: Beaver Creek Validation Error Statistics

	Current	Criteria
Error in total volume	5.500	10.000
Error in low flow recession	0.020	-0.010
Error in 50% lowest flows	6.500	-10.000
Error in 10% highest flows	-4.700	15.000
Error in storm volumes	4.500	15.000
Seasonal volume error	32.400	10.000
Summer storm volume error	12.600	15.000

Figure 4-6: Beaver Creek - HSPF Model Hydrologic Validation Results

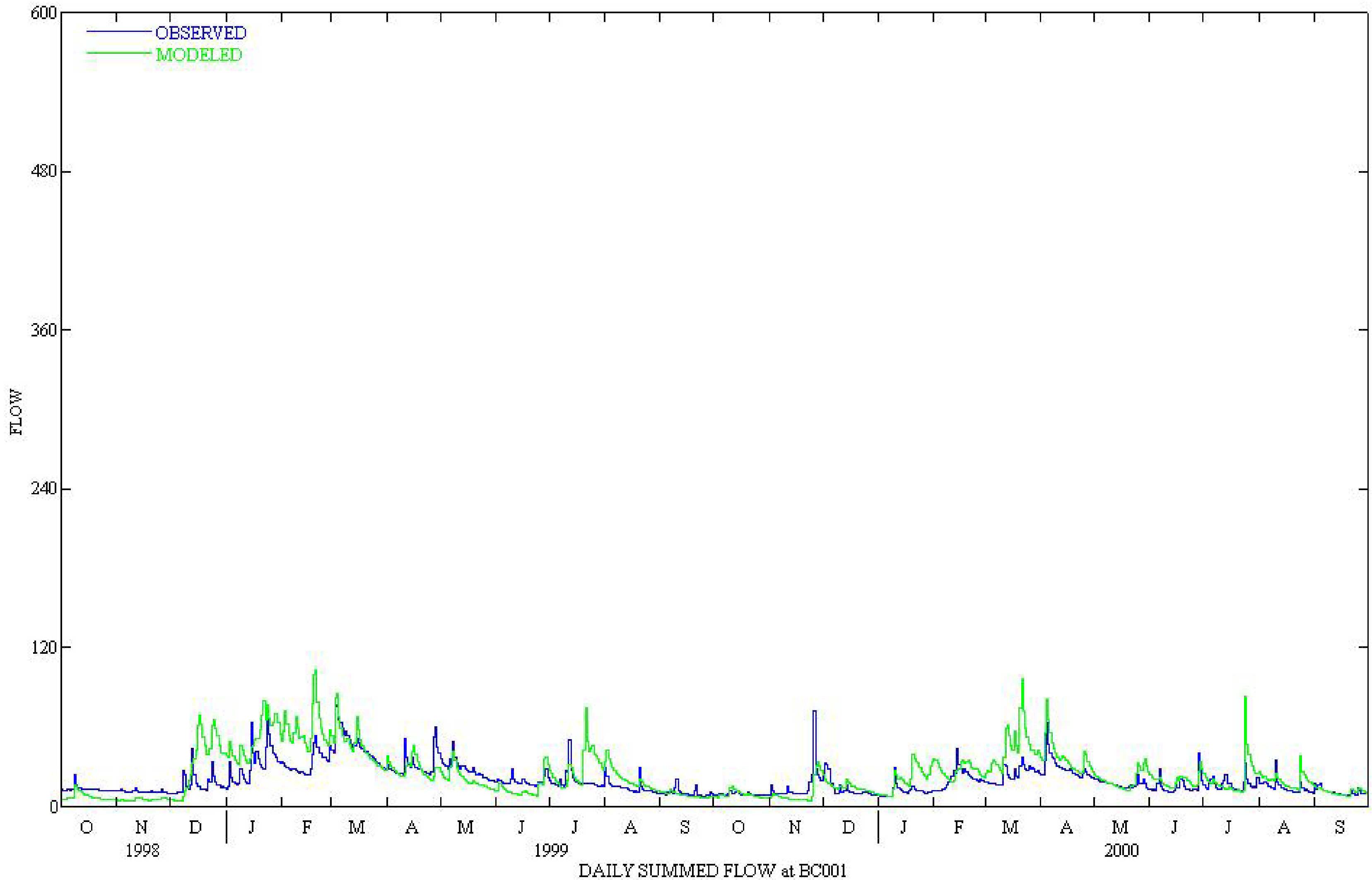


Table 4-14: Beaver Creek Validation Water Budget

Water Year	Surface Runoff (inches)	Interflow (inches)	Base flow (inches)	Surface runoff	Interflow	Base flow
1998	1.774	4.05	14.01	8.9%	20.4%	70.6%
1999	0.432	1.27	11.86	3.2%	9.4%	87.5%
Average	1.10	2.66	12.93	6.1%	14.9%	79.1%

There is a good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. The model result closely matches the observed flows during low flow conditions, base flow recession and storm peaks. The final parameter values of the calibrated model are listed in Table 4-15.

Table 4-15: Beaver Creek Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Beaver /Little Creek	Function of
			Min	Max	Min	Max		
FOREST	Fraction forest cover	None	0.00	0.5	0	0.95	0.0, 1.0	Forest cover
LZSN	Lower zone nominal soils moisture	In.	3	8	2	15	7.0-8.0	Soil properties
INFILT	Index to infiltration capacity	In/hr	0.01	0.25	0.001	0.5	0.08-0.12	Soil and cover properties
LSUR	Length of overland flow	Ft	200	500	100	700	300	Topography
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.03	Topography
KVARY	Groundwater recession variable	1/in	0	3	0	5	1.7	calibrate
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.90	calibrate
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40	Climate, vegetation

Parameter	Definition	Units	Typical		Possible		Beaver /Little Creek	Function of
			Min	Max	Min	Max		
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2	Soil properties
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.02	Geology
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.01	Riparian vegetation
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0.0-0.1	Marsh/ wetlands
CEPSC	Interception storage capacity	inches	0.03	0.2	0.01	0.4	Monthly[1]	Vegetation
UZSN	Upper zone nominal soils moisture	inches	0.10	1	0.05	2	0.8-1.6	Soil properties
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25	Surface condition
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	1.0-1.5	Soils, topography, land use
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.3-0.4	Soils, topography, land use
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	Monthly[1]	Vegetation
RETSC	Retention storage capacity of the surface	In						Land use
ACQOP	Rate of accumulation of constituent	#/day						Land use
SQOLIM	Maximum accumulation of constituent	#						Land use
WSQOP	Wash-off rate	In/hr						Land use
IOQC	Constituent concentration in interflow	#/CF					1416	
AOQC	Constituent concentration in active groundwater	#/CF					283	

Parameter	Definition	Units	Typical		Possible		Beaver /Little Creek	Function of
			Min	Max	Min	Max		
KS	Weighing factor for hydraulic routing						0.5	
FSTDEC	First order decay rate of the constituent	1/day					1.15	
THFST	Temperature correction coefficient for FSTDEC	none					1.07	

[1]Varies with Land Use

4.9.6 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off and kinetic rates for fecal coliform that best describe the fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available instream fecal coliform data and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated instream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The available instream water quality data plays a major factor in determining the calibration and validation periods for the model. In Section 3.0, the instream monitoring events conducted on Little Creek were summarized and a summary of frequency of the fecal coliform standard exceedance was presented. There were three distinct sampling events that can be summarized as follows:

- Sampling events in 1991 by DEQ,
- Sampling events in 1995 and 1996, by TDEC, and
- Sampling events in 2001 and 2002 by DEQ.

Consequently, the period from January 1990 to December 1991 was used for the water quality calibration of the model and the period from August 2001 to February 2002 was used for the model validation.

The fluctuations in the TDEC water quality data were substantial. The fecal coliform concentration increased by 10 fold in a 24-hour period during dry weather conditions. This situation would be impossible to represent under the existing watershed conditions and existing sources. To accurately simulate such fluctuations in the water quality data using the model, a more substantial loading from a specific point source or direct discharge would have to be added.

It is important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values. The model-simulated results and the observed fecal coliform values were plotted and are presented in Figure 4-7 and Figure 4-8. The goodness of fit for the water quality calibration was visually evaluated. These figures indicate that the model is well-calibrated since it can predict the range of fecal coliform concentration under the wet and dry weather conditions.

Figure 4-7: Water Quality Calibration

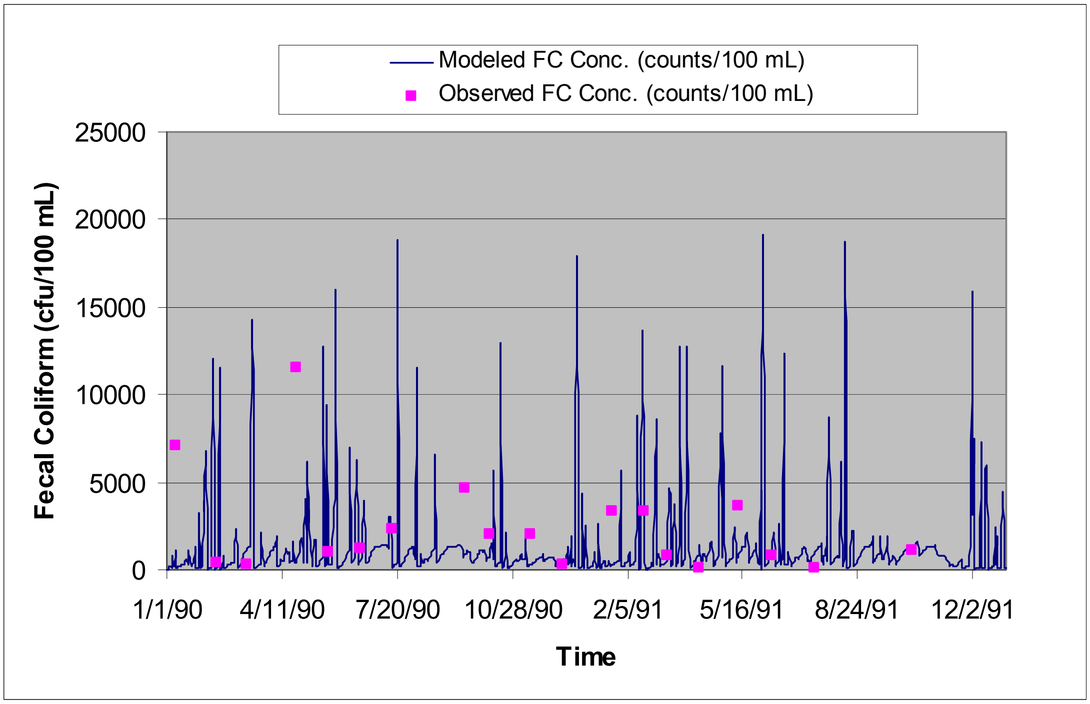
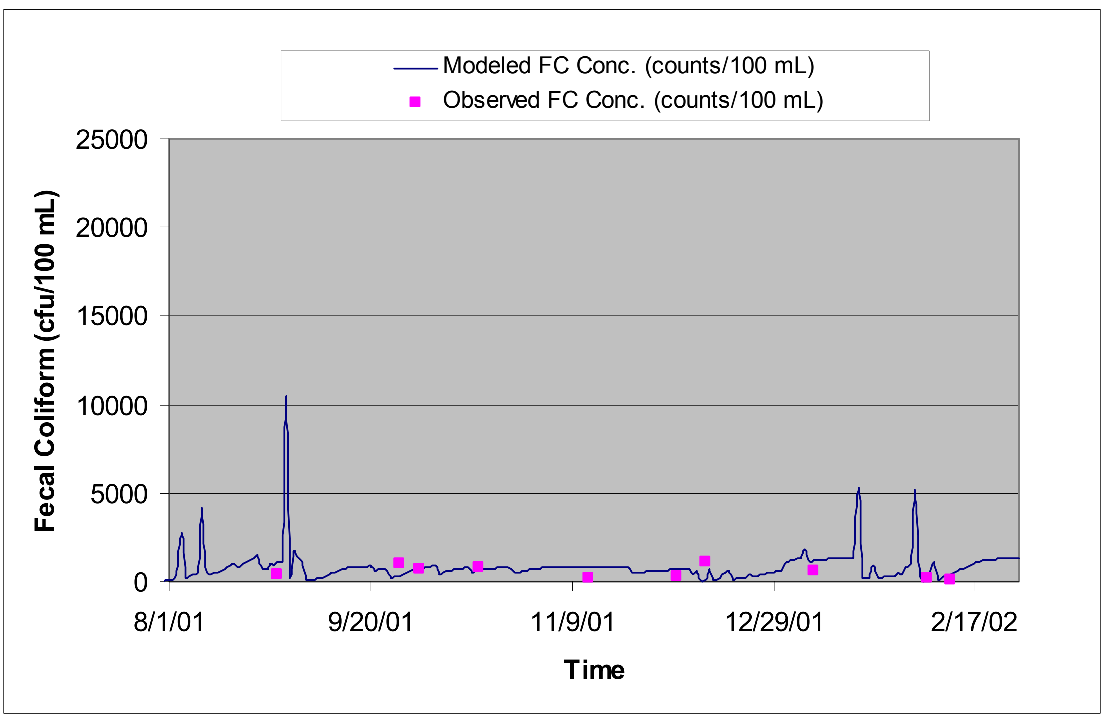


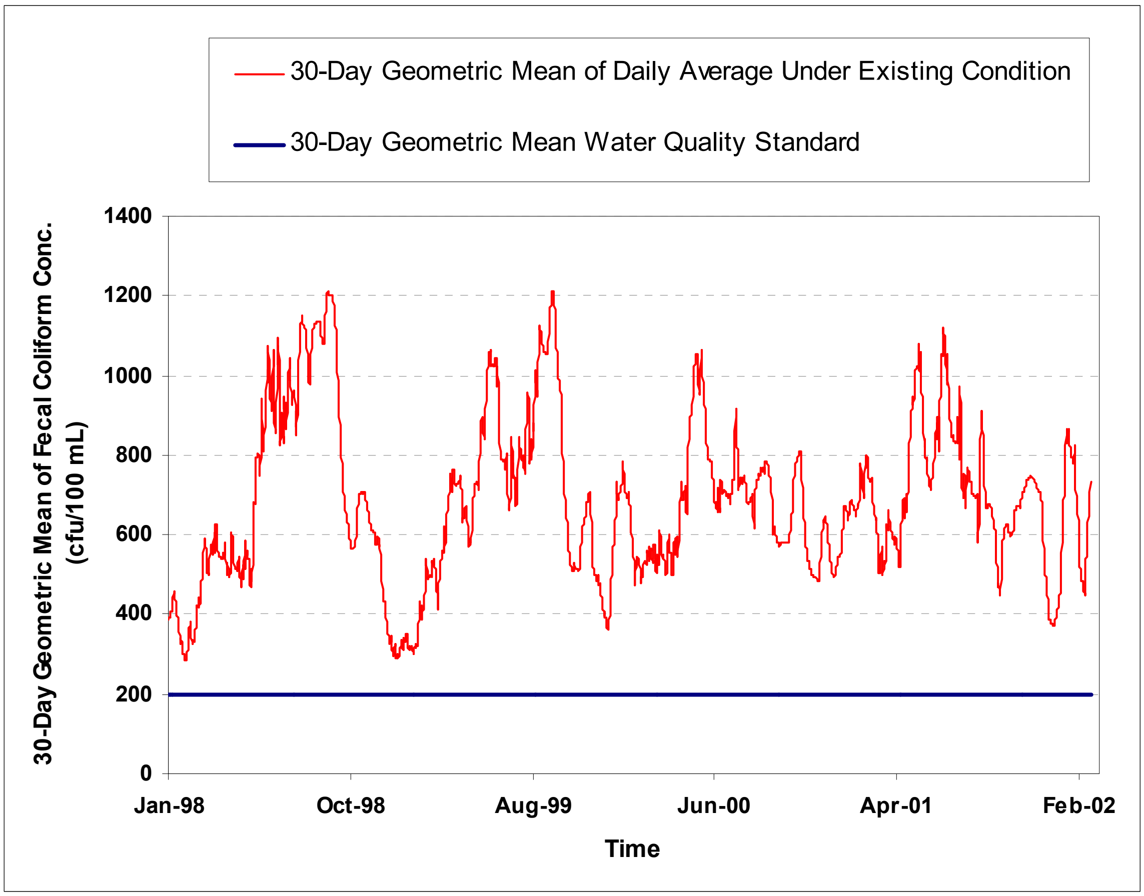
Figure 4-8: Water Quality Validation



4.10 Existing Fecal Coliform Loading

The existing fecal coliform loading was calculated based on the existing watershed conditions. The model input parameters reflect the conditions for the period from 1998 to 2002. Figure 4-9 shows the 30-day geometric mean fecal coliform concentration in Little Creek. The figure shows that the 200 cfu/100 ml standard was exceeded all the time.

Figure 4-9: Existing Conditions in Little Creek



The distribution of the existing fecal coliform load by source is presented in Table 4-16 and it shows that fecal coliform loading from pasture, croplands, and low density residential areas and direct deposition in the stream are the predominant sources of fecal coliform in the watershed.

Table 4-16: Fecal Coliform Distribution by Source

	Annual Average Fecal Coliform Loads	
Source	**cfu/year**	**Percent**
Forest	1.59E+11	0.06
Low Density Residential	4.36E+13	15.4
High Density Residential	9.58E+12	3.4
Pasture/Hay	1.62E+14	57.2
Row Crops	4.72E+13	16.7
Urban/Recreational Grass	4.54E+08	0.00
Commercial/Industrial/Transportation	1.94E+11	0.07
Septic load	3.91E+09	0.00
Direct deposition from cattle	2.05E+13	7.22
Direct deposition from wildlife	1.31E+09	0.001
Point Source (3)	8.29E+09	0.003
Total	2.83E+14	100

5.0 Allocation

For the Little Creek fecal coliform TMDL, allocation analysis was the third stage in development. Its purpose is to develop the framework for reducing fecal coliform loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety, 5% of TMDL.

There are likely to be several potential allocation strategies that would achieve the TMDL endpoint and will achieve water quality standards. Available control options will depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*) MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations; or
- Explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations.

The MOS will be explicitly incorporated in this TMDL. Incorporating a MOS of 5% will require that allocation scenarios be designed to meet the 30-day fecal coliform geometric mean standard of 190 cfu/100 ml with 0% exceedance.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response will provide a better understanding of the watershed conditions that lead to the standard violation and provide insight and direction in developing the TMDL allocation and implementation. Based on the sensitivity analysis and consultation from DCR, several allocation scenarios were developed: these are presented in the next section. For each scenario developed, the percent of days the water quality conditions violate both the 30-day geometric mean standard and the instantaneous fecal coliform standard is shown.

The results of the sensitivity analysis are presented in Appendix D.

5.3 Allocation Scenario Development

Allocation scenarios that would reduce the existing fecal coliform load to meet water quality standards were simulated using the HSPF model.

5.3.1 Wasteload Allocation

There are three permitted point sources discharges in the Little Creek watershed. These three on-site wastewater treatment facilities are permitted to discharge 1,000 gallons of treated water at fecal coliform concentration of 200 cfu/100 ml. The wasteload allocation for the three point sources is to maintain these facilities at their permit levels (1,000 gallons per day and 200 cfu/100 ml) (Table 5-1).

Table 5-1: Little Creek Wasteload Allocation (cfu/day)

VPDES ID	Existing Load	Allocated Load	Percent Reduction
VAG400007	7.57 E+6	7.57 E+6	0
VAG400006	7.57 E+6	7.5 E+6	0
VAG400230	7.57 E+6	7.57 E+6	0

5.3.2 Load Allocation

The reduction of nonpoint sources and direct deposition is included in the load allocation. A number of load allocation scenarios were developed in the process of determining the final TMDL load allocation scenario. The scenarios considered are presented in Table 5-2 and can be summarized as follows:

- Scenario 0 represents the existing loading, which is no reduction of any of the sources;
- Scenario 1 represents elimination of the human sources (straight pipes and septic systems which includes direct and land-load) and 50 percent reduction of the direct instream loading from livestock;
- Scenario 2 represents elimination of the human sources of fecal coliform (straight pipes and septic systems which includes direct and land-load) and a 75 percent reduction of the direct instream fecal coliform loading from livestock;
- Scenario 3 represents elimination of the human sources of fecal coliform (straight pipes and septic systems which includes direct and land-load) and the direct instream fecal coliform loading from livestock;
- Scenario 4 represents the fecal coliform loading from wildlife (all other sources are eliminated);
- Scenario 5 represents elimination of the human sources (straight pipes and septic systems which includes direct and land-load) and the direct instream deposition of fecal coliform from livestock and a 50 percent reduction of the direct deposition load from wildlife; and
- Scenario 6 represents elimination of the human sources (straight pipes and septic systems which includes direct and land-load) and the direct instream deposition of

fecal coliform from livestock and a 70 percent reduction of the direct deposition load from wildlife.

Table 5-2: Little Creek Load Allocation

Scenario Number	Reduction in Loadings from Existing Conditions (%)				
	Failing Septic Systems and Pipes	Direct Livestock	Nonpoint Source	Pets	Direct Wildlife
0	-	-	-	-	-
1	100	50	-	-	-
2	100	75	-	-	-
3	100	100	-	-	-
4	100	100	100	100	-
5	100	100	-	-	50
6	100	100	-	-	70

For the hydrologic period from January 1998 to February 2002, the fecal coliform loading and the instream fecal coliform concentrations were estimated for the scenarios presented above using the developed HSPF model of the Little Creek watershed. The load reductions corresponding to these allocation scenarios are presented in Table 5-3. The table shows the proposed load reduction under each scenario and the percent of days the 190 cfu/100 ml water quality standard was violated. The following conclusions can be made:

1. Under existing conditions, the water quality standard was violated all the time (Scenario 1);
2. Elimination of the human sources and the livestock direct instream deposition will result in a 71 percent violation of the water quality standard (Scenario 3);
3. The wildlife loading results in a 43 percent violation of the water quality standard (Scenario 4); and
4. No violation of the water quality standard was achieved by complete elimination of the human sources and livestock direct instream deposition, and a 70 percent reduction of the direct instream wildlife loading (Scenario 6).

Table 5-3: Little Creek Load Reduction under 30-Day Geometric Mean Standard

Scenario Number	Reduction in Loadings from Existing Conditions (%)					% days Geometric Mean > 190 counts/100ml
	Failed Septic Systems and Pipes	Direct Livestock	Nonpoint Source	Pets	Direct Wildlife	
0	-	-	-	-	-	100
1	100	50	-	-	-	95
2	100	75	-	-	-	92
3	100	100	-	-	-	71
4	100	100	100	100	-	43
5	100	100	-	-	50	2.4
6	100	100	-	-	70	0

5.4 TMDL Summary

Based on load allocation scenario analysis, a TMDL allocation plan to meet the 30-day geometric mean water quality standard goal of 190 cfu/100 ml requires:

- 100 percent reduction of human sources of fecal coliform from failed septic systems and straight pipes,
- 100 percent reduction of the direct instream fecal coliform loading from livestock, and
- 70 percent reduction of the direct instream fecal coliform loading from wildlife.

Table 5-4 shows the distribution of the annual average fecal coliform load under existing conditions and the TMDL allocation by source.

Table 5-4: Distribution of Annual Average Fecal Coliform Load under Existing Conditions

Source	Annual Average Fecal Coliform Loads		Percent Reduction
	Existing	Allocation	
Forest	1.59E+11	1.59E+11	0
Low Density Residential	4.36E+13	4.36E+13	0
High Density Residential	9.58E+12	9.58E+12	0
Pasture/Hay	1.62E+14	1.62E+14	0
Row Crops	4.72E+13	4.72E+13	0
Urban/Recreational Grass	4.54E+08	4.54E+08	0
Commercial/Industrial/ Transportation	1.94E+11	1.94E+11	0
Septic load	3.91E+09	0	100
Direct deposition from cattle	2.05E+13	0	100
Direct deposition from wildlife	1.31E+09	3.93E+08	70
Point Source (3)	8.29E+09	8.29E+09	0

Figure 5-1 shows the existing fecal coliform loading and the fecal coliform loading after applying the allocation above. A summary of the fecal coliform TMDL allocation plan loads for Little Creek is presented in Table 5-5.

Figure 5-1: Existing and Allocated Fecal Coliform Loadings

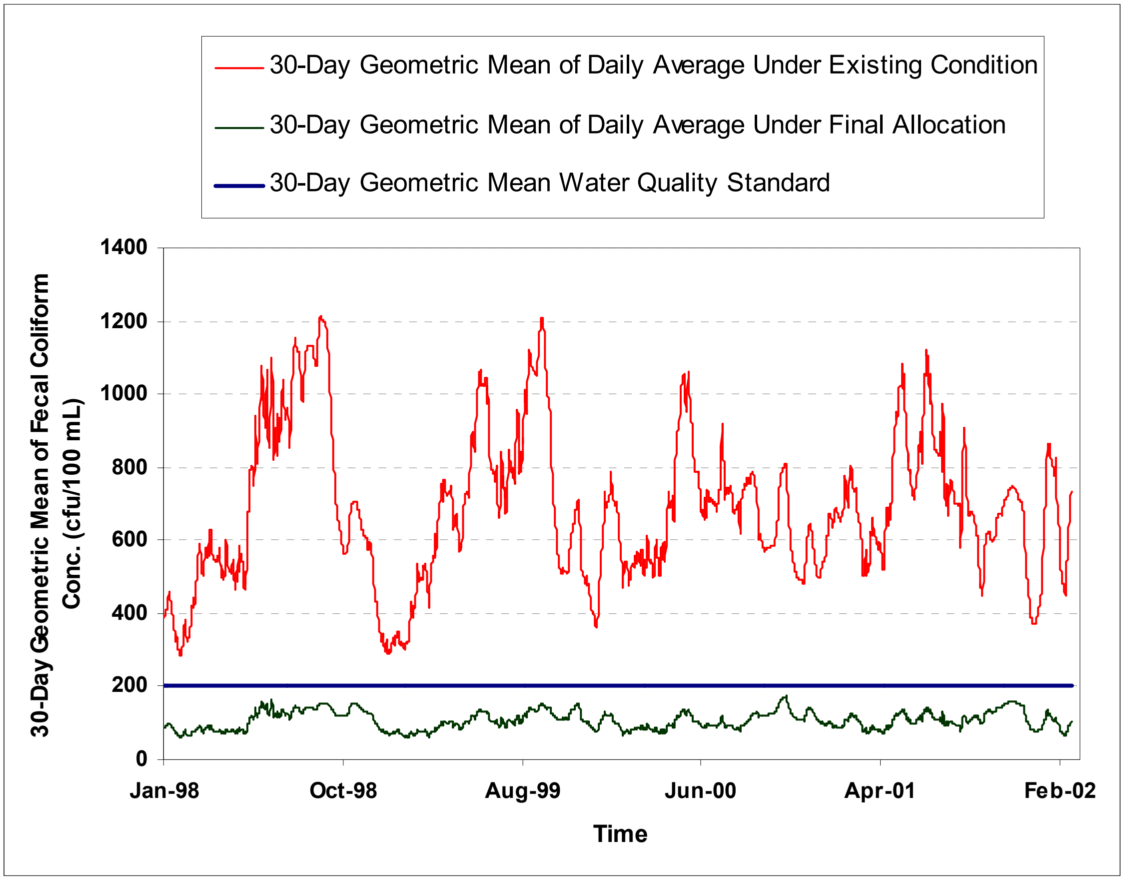


Table 5-5: Little Creek TMDL Allocation Plan Loads (cfu/year)

Point Sources (WLA)	Nonpoint source (LA)	Margin of safety (MOS)	TMDL
8.29E+09	2.63E+14	1.58E+13	2.79E+14

6.0 Implementation

6.1 TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are:

1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved;
2) it provides a measure of quality control, given the uncertainties that exist in any model;
3) it provides a mechanism for developing public support;
4) it helps to ensure the most cost effective practices are implemented first, and
5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

While specific stage I goals for BMP implementation will be established as part of the implementation plan development process, some general guidelines and suggestions are outlined below.

For the hydrologic period from January 1998 to February 2002, the fecal coliform loading and the instream fecal coliform concentrations were estimated for the scenarios presented in Table 6-1 using the developed HSPF model of the Little Creek watershed. For these scenarios, the frequency of violation of the instantaneous water quality standard was determined. Table 6-1 shows allocation scenarios and the percent of days the 1,000 cfu/100 ml water quality standard was violated. The following conclusions can be made:

1. Under existing conditions, the water quality standard was violated 40 percent of the time (Scenario 1);

2. Elimination of the human sources (straight pipes and septic systems) and the livestock direct instream deposition will result in a 10.2 percent violation of the water quality standard (Scenario 3);
3. The wildlife loading results in no violation of the water quality standard (Scenario 4); and
4. No violation of the water quality instantaneous standard was achieved by complete elimination of the human sources and livestock direct instream deposition, and a 50 percent reduction of the direct instream wildlife loading (Scenario 5).

Table 6-1: Little Creek Load Reduction under Instantaneous Standard

Scenario Number	Reduction in Loadings from Existing Conditions (%)					Percent of Days Exceed Inst. Standard (1000 cfu/100ml)
	Failing Septic Systems and Pipes	Direct Livestock	Nonpoint Source	Pets	Direct Wildlife	
0	-	-	-	-	-	40.2
1	100	50	-	-	-	11.8
2	100	75	-	-	-	11.0
3	100	100	-	-	-	10.2
4	100	100	100	100	-	0.0
5	100	100	-	-	50	9.6
6	100	100	-	-	70	9.3

In general, the Commonwealth intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, the most promising management practice in agricultural areas of the watershed is livestock exclusion from streams. This has been shown to be very effective in lowering fecal coliform concentrations in streams, both from the cattle deposits themselves and from additional buffering in the riparian zone. Additionally, reducing the human bacteria loading from failing septic systems and straight pipes should be a focus during the first stage because of its health implications. The effectiveness of addressing these two source categories was illustrated in Table 5-4 in the previous section.

6.2 Reasonable Assurance for Implementation

6.2.1 Follow-Up Monitoring

DEQ will continue to monitor Little Creek in accordance with its ambient monitoring program. DEQ and DCR will continue to use data from these monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

6.2.2 Regulatory Framework

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be developing a TMDL implementation plan, and the final step will be implementing the TMDL in order to attain water quality standards.

Section 303(d) of the Clean Water Act and current EPA regulations do not require the development of implementation strategies. However, including implementation plans as a TMDL requirement has been discussed for future federal regulations. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act directs DEQ in Section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters." The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. In future years, increases in Section 319 funding will be targeted toward TMDL implementation and watershed restoration. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement Program, the state's revolving loan program, and the Virginia Water Quality Improvement Fund.

6.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after the removal of all of the sources of fecal coliform (other than wildlife), the stream will not attain standards. As in the case of Little Creek, TMDL allocation reductions of this magnitude are not realistic and do not meet EPA's guidance for reasonable assurance. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** This is obviously an impractical action. Clearly, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. In such a case, after demonstrating that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs, the state may decide to adopt site specific criteria based on natural background levels of fecal coliforms. As stated above, watershed stakeholders and EPA will be able to provide comment during this process.

7.0 Public Participation

The development of the Little Creek TMDL would not have been possible without public participation. The first public meeting was held in the City of Bristol on December 6, 2001 to discuss the process for TMDL development, source assessment input and bacterial source tracking data; 17 people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. A public notice newsletter was prepared by DEQ. Copies were mailed to county residents and were delivered door to door in the area of the Little Creek watershed within the City of Bristol. A public meeting notice was published in the Bristol Herald on December 2, 2001. There was a 30-day public comment period during which no written comments were received.

The second public meeting was held in the City of Bristol on March 7, 2002 to discuss the draft TMDL; 22 people attended. Copies of the presentation were available for public distribution. The meeting was public noticed in the Virginia Register. A public meeting notice newsletter was prepared by DEQ and mailed to county and city residents. A public meeting notice was also e-mailed to members of two local watershed groups: Boone Watershed Partnership and Beaver Creek Watershed Alliance. A public meeting notice was published in the Bristol Herald on March 3, 2002.

The draft TMDL report was completed on March 22, 2002. The report was mailed to interested stakeholders. There was a 30-day public comment period that ended on April 15, 2002. No written comments were received.

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Glossary

Allocations. Allocations are that portion of a receiving water's loading capacity that is attributed to one of its existing or future sources (nonpoint or point) of pollution or to natural background sources. (Wasteload allocation (WLA) is that portion of the loading capacity allocated to an existing or future point source and a load allocation (LA) is that portion allocated to an existing or future nonpoint source or to natural background source. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)

Ambient water quality. Concentration of water quality constituent as measured within the waterbody.

Assimilative capacity. The amount of pollutant load that can be discharged to a specific waterbody without exceeding water quality standards. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharges substance without impairing water quality or harming aquatic life.

Bacteria. Single-celled microorganisms that lack a fully-defined nucleus and contain no chlorophyll. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources). A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best management practices (BMPs). Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration. The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Channel. A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.

Coliform bacteria. See Total coliform bacteria.

Combined sewer system (CSS). Sewer system that receives both domestic wastewater and stormwater and conducts the mixture to a treatment facility.

Concentration. Amount of a substance or material in a given unit volume of solution. Usually measured in milligrams per liter (mg/l) or parts per million (ppm).

Contamination. Act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Cost-share program. Program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs are paid by the producer.

Critical condition. The combination of environmental factors that results in just meeting the water quality criterion and has an acceptably low frequency of occurrence.

Cross-sectional area. Wet area of a waterbody normal to the longitudinal component of the flow.

Cryptosporidium. See protozoa.

Decay. Gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Deterministic model. A model that does not include built-in variability: same input will always equal the same output.

Die-off rate. The first-order decay rate for bacteria, pathogens, and viruses. Die-off depends on the particular type of water body (i.e. stream, estuary , lake) and associated factors that influence mortality.

Dilution. Addition of less concentrated liquid (water) that results in a decrease in the original concentration.

Direct runoff. Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.

Discharge. Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

Discharge permits (NPDES). A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. It is called the NPDES because the permit process was established under the National Pollutant

Discharge Elimination System, under provisions of the Federal Clean Water Act.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Effluent limitation. Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.

Endpoint. An endpoint is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints that are commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance. A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints.

Enteric. Of or within the gastrointestinal tract.

Enterococci. A subgroup of the fecal streptococci that includes S. faecalis and S. faecium. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 C and 45 C. Enterococci are a valuable bacterial indicator for determining the extent of fecal contamination of recreational surface waters.

Epidemiology. All the elements contributing to the occurrence or non-occurrence of a disease in a population; ecology of a disease.

Escherichia coli. A subgroup of the fecal coliform bacteria. *E. coli* is part of the normal intestinal flora in humans and animals and is, therefore, a direct indicator of fecal contamination in a waterbody. The O157 strain, sometimes transmitted in contaminated waterbodies, can cause serious infection resulting in gastroenteritis. See Fecal coliform bacteria.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

Fecal coliform bacteria. A subset of total coliform bacteria that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of water. They are measured by running the standard total coliform test at an elevated temperature (44.5 °C). Fecal coliform is approximately 20% of total coliform. See also Total coliform bacteria.

Fecal streptococci. These bacteria include several varieties of streptococci that originate in the gastrointestinal tract of warm-blooded animals such as humans (*Streptococcus faecalis*) and domesticated animals such as cattle (*Streptococcus bovis*) and horses (*Streptococcus equinus*).

Feedlot. A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.

Flux. Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.

Giardia lamblia. See protozoa.

Gradient. The rate of decrease (or increase) of one quantity with respect to another; for example, the rate of decrease of temperature with depth in a lake.

Groundwater. The supply of fresh water found beneath the earth s surface, usually in aquifers, which supply wells and springs. Because groundwater is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.

Hydrology. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Indicator. Measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.

Indicator organism. Organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.

Infectivity. Ability to infect a host.

Initial mixing zone. Region immediately downstream of an outfall where effluent dilution processes occur. Because of the combined effects of the effluent buoyancy, ambient stratification, and current, the prediction of initial dilution can be involved.

Insolation. Exposure to the sun’s rays.

Irrigation. Applying water or wastewater to land areas to supply the water and nutrient needs of plants.

Karst geology. Solution cavities and closely-spaced sinkholes formed as a result of dissolution of carbonate bedrock.

Land application. Discharge of wastewater onto the ground for treatment or reuse. (See: irrigation)

Leachate. Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, groundwater, or soil.

Load, Loading, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA). The portion of a receiving water s loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. (40 CFR 130.2(g))

Loading capacity (LC). The greatest amount of loading that a water can receive without violating water quality standards.

Low-flow. Stream flow during time periods where no precipitation is contributing to runoff to the stream and contributions from groundwater recharge are low. Low flow results in less water available for dilution of pollutants in the stream. Due to the limited flow, direct discharges to the stream dominate during low flow periods. Exceedences of water quality standards during low flow conditions are likely to be caused by direct discharges such as point sources, illicit discharges, and livestock or wildlife in the stream.

Margin of Safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Mass balance. An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.

Mass loading. The quantity of a pollutant transported to a waterbody.

Mathematical model. A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one, or more, individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.

Mitigation. Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those which restore, enhance, create, or replace damaged ecosystems.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

National Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the Clean Water Act.

Natural background levels. Natural background levels represent the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.

Natural waters. Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

Nonpoint source. Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Numeric Targets. A measurable value determined for the pollutant of concern which is expected to result in the attainment of water quality standards in the listed waterbody.

Organic matter. The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substance synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.

Outfall. Point where water flows from a conduit, stream, or drain.

Pathogen. Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Permit. An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Permit Compliance System (PCS). Computerized management information system which contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.

Phased approach. Under the phased approach to TMDL development, LAs and WLAs are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. (CWA Section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Protozoa. Single-celled organisms that reproduce by fission and occur primarily in the aquatic environment. Waterborne pathogenic protozoans of primary concern include Giardia lamblia and Cryptosporidium, both of which affect the gastrointestinal tract.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Publicly Owned Treatment Works (POTW). Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

Raw sewage. Untreated municipal sewage.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, groundwater formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Residence time. Length of time that a pollutant remains within a section of a waterbody. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

Respiration. Biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of the energy required to sustain life; during respiration, oxygen is consumed and carbon dioxide is released.

Restoration. Return of an ecosystem to a close approximation of its condition prior to disturbance.

Runoff. That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Safe Drinking Water Act. The Safe Drinking Water Act authorizes EPA to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants that may be found in drinking water. EPA, states, and water systems then work together to make sure these standards are met.

Sanitary sewer overflow (SSO). When wastewater treatment systems overflow due to unforseen pipe blockages or breaks, unforseen structural, mechanical, or electrical failures, unusually wet weather conditions, insufficient system capacity, or a deteriorating system.

Scoping modeling. Involves simple, steady-state analytical solutions for a rough analysis of the problem.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a system of tile lines or a pit for disposal of the liquid effluent (sludge) that remains after decomposition of the solids by bacteria in the tank; must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. "Sanitary" sewers carry household, industrial, and commercial waste. "Storm" sewers carry runoff from rain or snow. "Combined" sewers handle both.

Simulation. Refers to the use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04); degrees (2 degrees 18 minutes), or percent (4 percent).

Stakeholder. Those parties likely to be affected by the TMDL.

Steady-state model. Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations.

STORET. U.S. Environmental Protection Agency (EPA) national water quality database for STORage and RETrieval (STORET). Mainframe water quality database that includes physical, chemical, and biological data measured in waterbodies throughout the United States.

Storm runoff. Stormwater runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or waterbodies or is routed into a drain or sewer system.

Stormwater. The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel, or a constructed infiltration facility.

Stormwater management models (SWMM). USEPA mathematical model that simulates the hydraulic operation of the combined sewer system and storm drainage sewershed.

Stratification (of waterbody). Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water.

Stressor. Any physical, chemical, or biological entity that can induce an adverse response.

Surface runoff. Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other groundwater collectors directly influenced by surface water.

Technology-based limits. Industry-specified effluent limitations applied to a discharge when it will not cause a violation of water quality standards at low stream flows. Usually applied to discharges into large rivers.

Three-dimensional model (3-D). Mathematical model defined along three spatial coordinates where the water quality constituents are considered to vary over all three spatial coordinates of length, width, and depth.

Topography. The physical features of a surface area including relative elevations and the position of natural and man-made features.

Total coliform bacteria. A particular group of bacteria, found in the feces of warm-blooded animals, that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaded bacteria which ferment lactose with gas formation within 48 hours at 35° . Note that many common soil bacteria are also total coliforms, but do not indicate fecal contamination. See also fecal coliform bacteria.

Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard

Tributary. A lower order stream compared to a receiving waterbody. “Tributary to” indicates the largest stream into which the reported stream or tributary flows.

Turbidity. The amount of light that is scattered or absorbed by a fluid.

Two-dimensional model (2-D). Mathematical model defined along two spatial coordinates where the water quality constituents are considered averaged over the third remaining spatial coordinate. Examples of 2-D models include descriptions of the variability of water quality properties along: (a) the length and width of a river that incorporates vertical averaging or (b) length and depth of a river that incorporates lateral averaging across the width of the waterbody.

Urban runoff. Water containing pollutants like oil and grease from leaking cars and trucks; heavy metals from vehicle exhaust; soaps and grease removers; pesticides from gardens; domestic animal waste; and street debris, which washes into storm drains and enters surface waters.

Validation (of a model). Process of determining how well the mathematical representation of the physical processes of the model code describes the actual system behavior.

Verification (of a model). Testing the accuracy and predictive capabilities of the calibrated model on a data set independent of the data set used for calibration.

Virus. Submicroscopic pathogen consisting of a nucleic acid core surrounded by a protein coat. Requires a host in which to replicate (reproduce).

Wasteload allocation (WLA). The portion of a receiving water s loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

Wastewater. Usually refers to effluent from a sewage treatment plant.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water in order to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Water quality criteria. Elements of state water quality standards expressed as constituent concentrations, levels, or narrative statement, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.

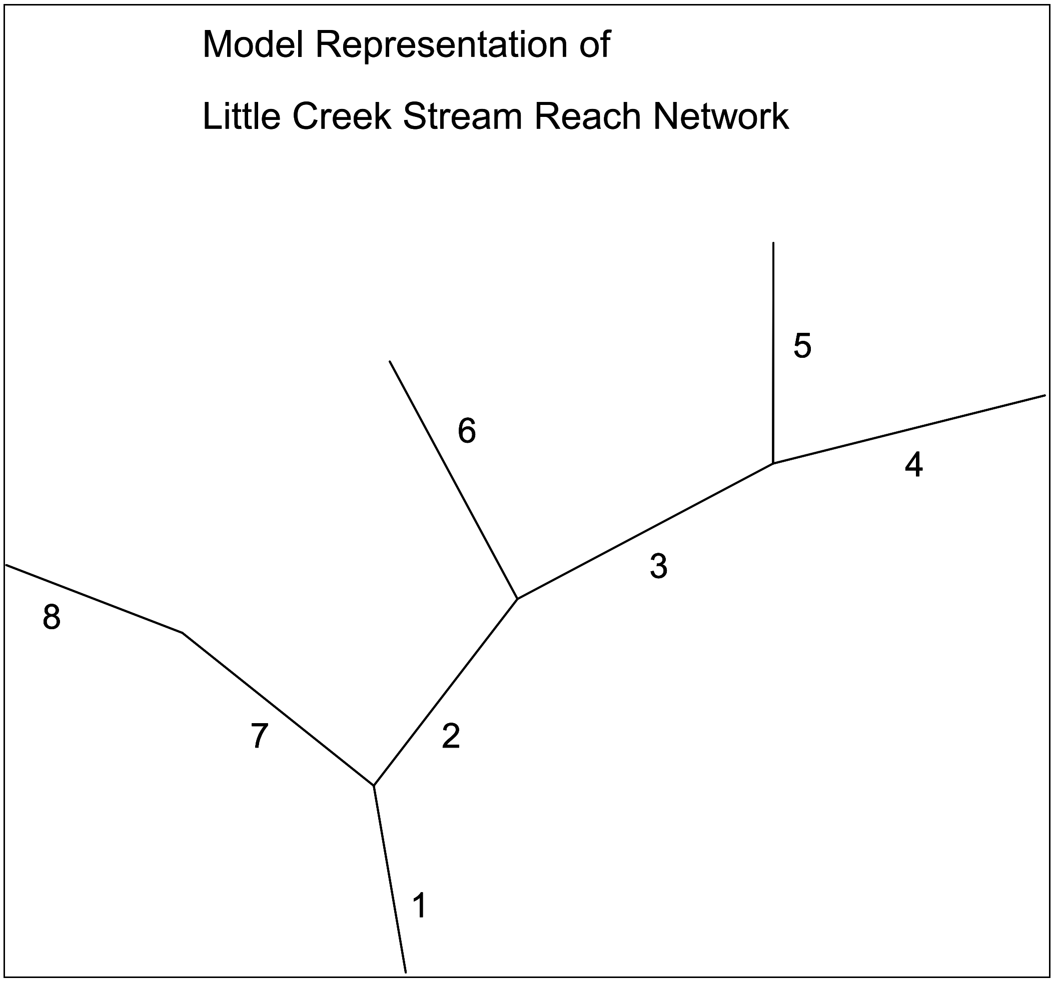
Water quality standard. State or federal law or regulation consisting of a designated use or uses for the waters of the United States, water quality criteria for such waters based upon such uses, and an antidegradation policy and implementation procedures. Water quality standards protect the public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wetlands. An area that is constantly or seasonally saturated by surface water or groundwater with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, marshes, and estuaries.

Appendix A

Model Representation of Stream Reach Networks


Model Representation of
Little Creek Stream Reach Network
5
6
4
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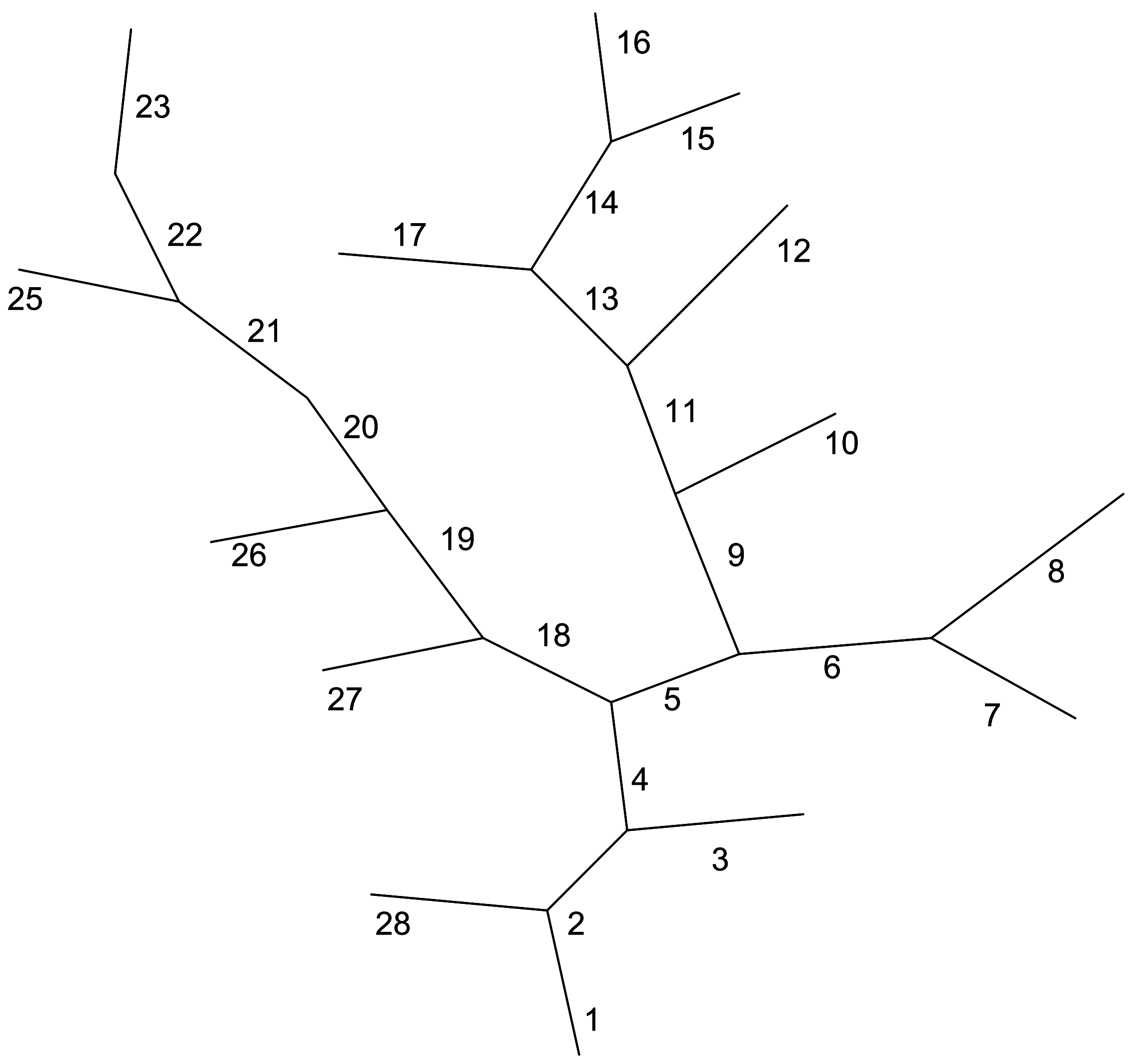
7
2
1

Model Representation of

Beaver Creek Stream Reach Network



Appendix B

Monthly Fecal Coliform Build-up Rates

Table B-1: Little Creek – Monthly Build-up Rates (cfu/ac/day)

Land use	JAN	FEB	MAR	APR	MAY	JUN
Forest	3.36E+07	3.36E+07	3.36E+07	3.36E+07	3.36E+07	3.36E+07
Low Intensity Reside	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10
Pasture/Hay	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10
Row Crops	3.00E+08	6.00E+10	6.00E+10	1.00E+11	4.00E+10	1.00E+11
High Intensity Resid	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10
Urban/Rec Grasses	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07
Comm/Ind/Trnsprt	7.46E+07	7.46E+07	7.46E+07	7.46E+07	7.46E+07	7.46E+07
Quarries/Strip Mines	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07

Table B-2: Little Creek – Monthly Build-up Rates (cfu/ac/day)

Land use	JUL	AUG	SEP	OCT	NOV	DEC
Forest	3.36E+07	3.36E+07	3.36E+07	3.36E+07	3.36E+07	3.36E+07
Low Intensity Reside	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10
Pasture/Hay	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10
Row Crops	4.00E+10	1.00E+11	6.00E+10	1.00E+11	3.00E+08	6.00E+10
High Intensity Resid	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10	1.26E+10
Urban/Rec Grasses	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07
Comm/Ind/Trnsprt	7.46E+07	7.46E+07	7.46E+07	7.46E+07	7.46E+07	7.46E+07
Quarries/Strip Mines	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07	2.20E+07

Table B-3: Little Creek Monthly Direct Deposition Rates

Month	Cattle cfu/month	Wildlife cfu/month	Human cfu/month
1	8.69E+11	1.09E+08	3.26E+08
2	7.85E+11	1.09E+08	3.26E+08
3	2.17E+12	1.09E+08	3.26E+08
4	2.10E+12	1.09E+08	3.26E+08
5	2.17E+12	1.09E+08	3.26E+08
6	2.10E+12	1.09E+08	3.26E+08
7	2.17E+12	1.09E+08	3.26E+08
8	2.17E+12	1.09E+08	3.26E+08
9	2.10E+12	1.09E+08	3.26E+08
10	2.17E+12	1.09E+08	3.26E+08
11	8.41E+11	1.09E+08	3.26E+08
12	8.69E+11	1.09E+08	3.26E+08

Appendix C

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table C-1 Fecal Coliform Load: Existing Condition (counts/acre/month)

Month	Comm/Ind/ Trnsprt	Forest	Impervious	Low Intensity Resid	Pasture/Hay	Row Crops	Hi Intensity Resid	Urban/Recreational Grass	Quarries/Strip
1	2.50E+07	2.56E+06	0.00E+00	2.91E+09	6.77E+09	6.47E+09	3.07E+09	6.65E+06	6.65E+06
2	4.60E+07	3.12E+06	0.00E+00	5.87E+09	1.19E+10	2.53E+10	6.00E+09	1.09E+07	1.09E+07
3	9.74E+07	5.70E+06	0.00E+00	1.37E+10	2.81E+10	8.43E+10	1.39E+10	2.11E+07	2.11E+07
4	1.26E+08	1.64E+07	0.00E+00	1.88E+10	3.93E+10	1.10E+11	1.89E+10	2.93E+07	2.93E+07
5	5.05E+07	4.43E+06	0.00E+00	7.19E+09	1.47E+10	4.82E+10	7.24E+09	1.01E+07	1.01E+07
6	1.14E+08	8.56E+06	0.00E+00	1.66E+10	3.42E+10	9.15E+10	1.67E+10	2.17E+07	2.17E+07
7	1.06E+08	3.04E+06	0.00E+00	1.62E+10	3.64E+10	1.08E+11	1.63E+10	2.40E+07	2.40E+07
8	2.58E+07	1.13E+06	0.00E+00	3.65E+09	8.59E+09	2.54E+10	3.69E+09	4.84E+06	4.84E+06
9	4.23E+05	1.52E+05	0.00E+00	3.10E+07	7.00E+07	2.05E+08	3.13E+07	2.34E+05	2.34E+05
10	7.90E+05	1.94E+05	0.00E+00	6.51E+07	7.79E+07	2.48E+08	6.59E+07	3.94E+05	3.94E+05
11	1.97E+06	4.41E+05	0.00E+00	1.83E+08	4.10E+08	6.25E+08	1.99E+08	7.77E+05	7.77E+05
12	6.77E+06	1.34E+06	0.00E+00	6.99E+08	1.50E+09	1.72E+09	7.18E+08	2.45E+06	2.45E+06

Table C-2 Fecal Coliform Load Allocation Run (counts/acre/month)

Month	Comm/Ind/ Trnsprt	Forest	Impervious	Low Intensity Resid	Pasture/Hay	Row Crops	Hi Intensity Resid	Urban/Recreational Grass	Quarries/Strip
1	2.50E+07	2.56E+06	0.00E+00	2.91E+09	6.77E+09	6.47E+09	3.07E+09	6.65E+06	6.65E+06
2	4.60E+07	3.12E+06	0.00E+00	5.87E+09	1.19E+10	2.53E+10	6.00E+09	1.09E+07	1.09E+07
3	9.74E+07	5.70E+06	0.00E+00	1.37E+10	2.81E+10	8.43E+10	1.39E+10	2.11E+07	2.11E+07
4	1.26E+08	1.64E+07	0.00E+00	1.88E+10	3.93E+10	1.10E+11	1.89E+10	2.93E+07	2.93E+07
5	5.05E+07	4.43E+06	0.00E+00	7.19E+09	1.47E+10	4.82E+10	7.24E+09	1.01E+07	1.01E+07
6	1.14E+08	8.56E+06	0.00E+00	1.66E+10	3.42E+10	9.15E+10	1.67E+10	2.17E+07	2.17E+07
7	1.06E+08	3.04E+06	0.00E+00	1.62E+10	3.64E+10	1.08E+11	1.63E+10	2.40E+07	2.40E+07
8	2.58E+07	1.13E+06	0.00E+00	3.65E+09	8.59E+09	2.54E+10	3.69E+09	4.84E+06	4.84E+06
9	4.23E+05	1.52E+05	0.00E+00	3.10E+07	7.00E+07	2.05E+08	3.13E+07	2.34E+05	2.34E+05
10	7.90E+05	1.94E+05	0.00E+00	6.51E+07	7.79E+07	2.48E+08	6.59E+07	3.94E+05	3.94E+05
11	1.97E+06	4.41E+05	0.00E+00	1.83E+08	4.10E+08	6.25E+08	1.99E+08	7.77E+05	7.77E+05
12	6.77E+06	1.34E+06	0.00E+00	6.99E+08	1.50E+09	1.72E+09	7.18E+08	2.45E+06	2.45E+06

Appendix D

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Little Creek flows through both rural and urban settings. Potential sources of fecal coliform include point sources and land-based sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model input parameters on the fecal coliform annual loading and the fecal coliform concentration in Little Creek. For the hydrologic period, October 1997 to September 1998, the model was run under various land based and the direct deposition loading scenarios which include the following:

- 10 percent increase in land based loads
- 10 percent decrease in land based loads
- 100 percent increase in land based loads
- 10 percent decrease in land based loads
- 10 percent increase in direct deposition loads
- 10 percent decrease in direct deposition loads
- 100 percent increase in direct deposition loads
- 100 percent decrease in direct deposition loads

The results of the sensitivity analysis are presented in Figures D-1, D-2, and D-3. Based on these figures it can be seen that a reduction of the direct deposition load is more effective in reducing the instream fecal coliform concentration under low flow condition and consequently meeting the water quality targets for Little Creek.

Figure D-1:

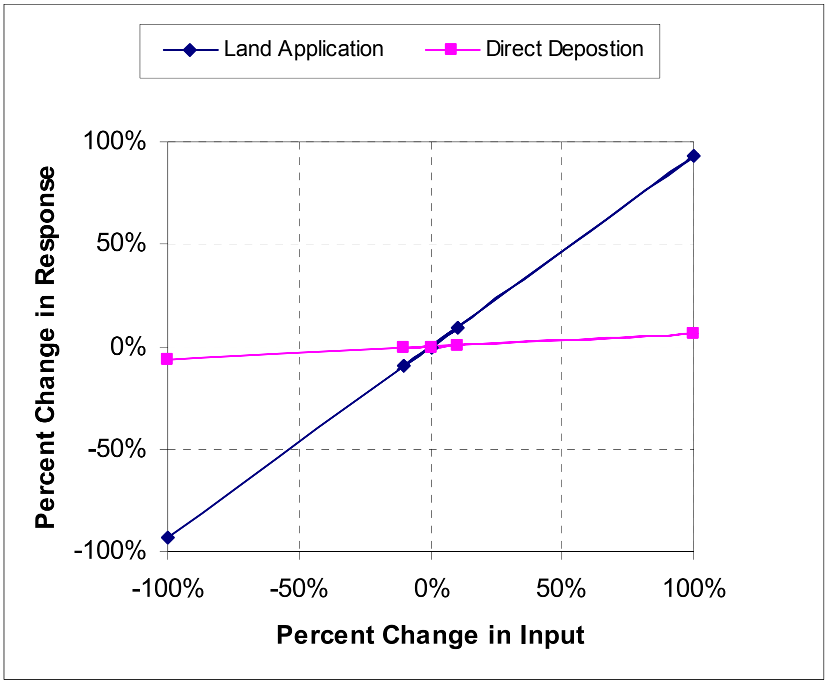


Figure D-2

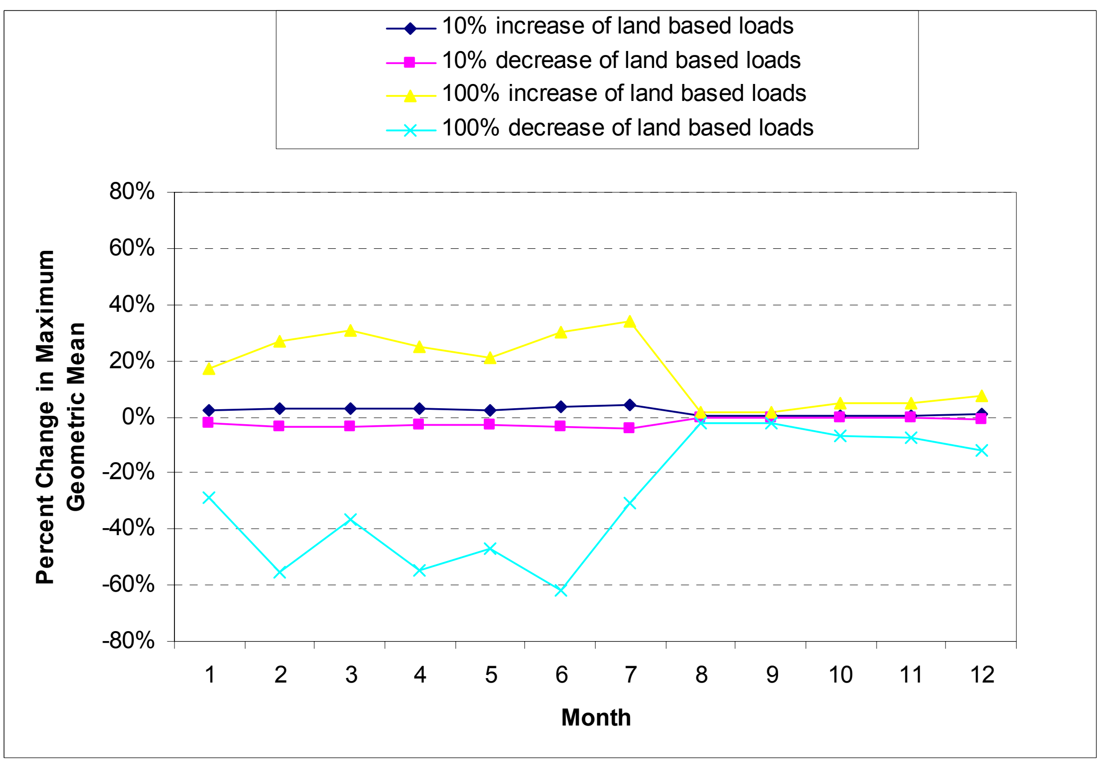
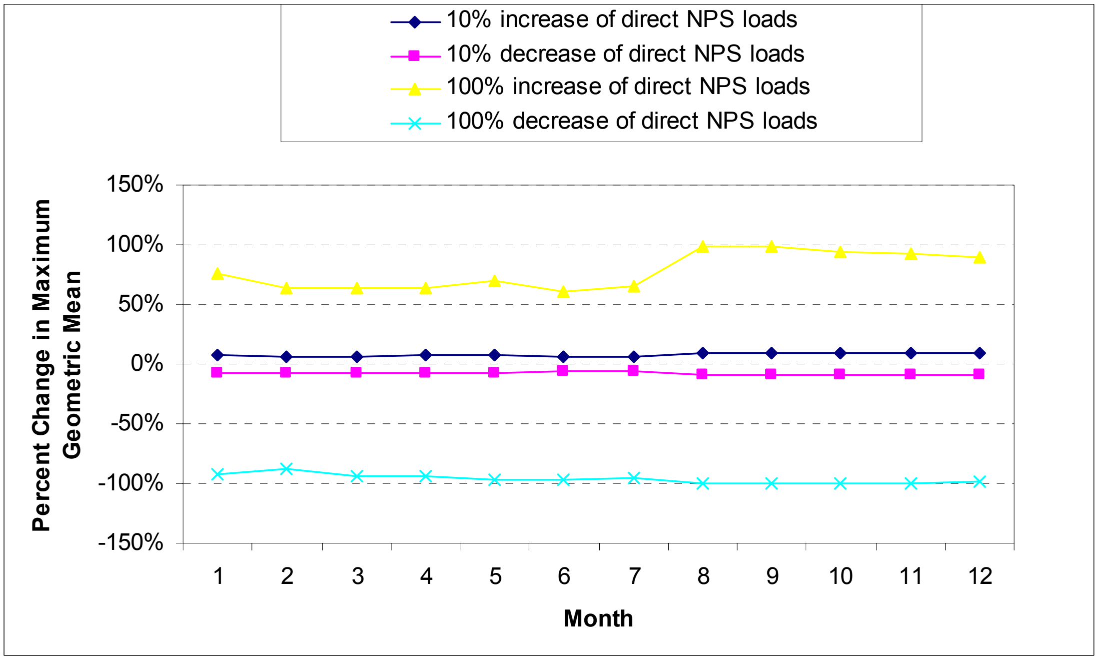


Figure D-3


10% increase of direct NPS loads
10% decrease of direct NPS loads
100% increase of direct NPS loads
100% decrease of direct NPS loads
Percent Change in Maximum Geometric Mean
150%
100%
50%
0%
-50%
-100%
-150%
1
2
3
4
5
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